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(54) **Laser scanning system and scanning method for reading 1-d and 2-d barcode symbols.**

(57) Optical scanning of barcode symbols is carried out first in an aim mode wherein the symbol is scanned using a first scan pattern that is relatively small and dense so as to be visible to the user, and thereafter using a second, larger, more robust scan pattern for decoding. The preferred scanner module has a scanner mirror which is mounted to a bracket by way of a leaf spring, allowing the mirror to oscillate in one direction. This is hung from a stationary chassis by means of two strips of mylar film, which are themselves protected against mechanical shock by pins which pass through holes in the bracket. The pins provide accurate alignment of the bracket with respect to the chassis.

EP 0 653 723 A2

This invention relates generally to hand-held scanning systems which "read" indicia, such as barcode symbols, and in particular to systems and methods for scanning one-dimensional (1-D) and two-dimensional (2-D) barcode symbols with a first scan pattern that is relatively small and dense so as to be visible to the user, and thereafter a second, larger and more robust scan pattern for decoding. The invention also relates to scanners operable in both portable (hand-held) and surface mounted (hands-free) modes for reading various types of indicia. The invention further relates to novel miniature assemblies capable of 1-D and 2-D scanning.

It further relates to a scanner module for use in an optical scanner, for example, a bar code scanner.

Various optical readers and scanning systems have been developed for reading barcode symbols appearing on a label or the surface of an article. The barcode symbol itself is a coded pattern of indicia comprised of a series of bars of various widths spaced apart from one another to bound spaces of various widths, the bars and spaces having different light-reflecting characteristics. The readers and scanning systems electro-optically transform the graphic indicia into electrical signals, which are decoded into alpha-numerical characters intended to be descriptive of the article or some characteristic of it. Such characters typically are represented in digital form, and utilized as an input to a data processing system for applications in point-of-sale processing, inventory control and the like. Scanning systems of this general type have been disclosed, for example, in U.S. Patent Nos. 4,251,798; 4,360,798; 4,369,361; 4,387,297; 4,409,470 and 4,460,120, all assigned to the assignee of the present invention.

One embodiment of such a scanning system, as disclosed in some of the above patents, resides in, inter alia, a hand-held, portable laser scanning head supported by a user. The scanning head is configured to enable the user to aim the head at a target to emit a light beam toward a symbol to be read. The light source is a laser scanner typically in the form of a gas or semiconductor laser element. Use of semiconductor devices as the light source in scanning systems is particularly desirable because of the small size, low cost and low power requirements of semiconductor lasers. The laser beam is optically modified, typically by a lens, to form a beam spot of a certain size at the target distance. Preferably, the beam spot size at the target distance is approximately the same as the minimum width between regions of different light reflectivity, i.e., the bars and spaces of the symbol.

The barcode symbols are formed from bars or elements typically rectangular in shape with a variety of possible widths. The specific arrangement of elements defines the character represented according to a set of rules and definitions specified by the code or "symbology" used. The relative size of the bars and spaces is determined by the type of coding used, as is the actual size of the bars and spaces. The number of characters per inch represented by the barcode symbol is referred to as the density of the symbol. To encode a desired sequence of characters, a collection of element arrangements are concatenated together to form the complete barcode symbol, with each character of the message being represented by its own corresponding group of elements. In some symbologies a unique "start" and "stop" character is used to indicate where the barcode begins and ends. A number of different barcode symbologies exist. These symbologies include UPC/EAN, Code 39, Code 128, Codabar, and Interleaved 2 or 5.

In order to increase the amount of data that can be represented or stored on a given amount of surface area, several new barcode symbologies have recently been developed. One of these new code standards, Code 49, introduces a "two-dimensional" concept by stacking rows of characters vertically instead of extending the bars horizontally. That is, there are several rows of bar and space pattern, instead of only one row. The structure of Code 49 is described in U.S. Patent 4,794,239, which is hereby incorporated by reference.

A one-dimensional single-line scan, as ordinarily provided by hand-held readers, functions by repetitively scanning the light beam in a line or series of lines across the symbol using a scanning component such as a mirror disposed in the light path. The scanning component may either sweep the beam spot across the symbol and trace a scan line across and past the symbol, or scan the field in view of the scanner, or do both.

Scanning systems also include a sensor or photodetector, usually of semiconductor type, which functions to detect light reflected from the symbol. The photo-detector is therefore positioned in the scanner or in an optical path in which it has a field of view which extends across and slightly past the symbol. A portion of the reflected light which is reflected off the symbol is detected and converted into an electrical signal, and electronic circuitry or software decodes the electrical signal into a digital representation of the data represented by the symbol that has been scanned. For example, the analog electrical signal from the photodetector may typically be converted into a pulse width modulated digital signal, with the widths corresponding to the physical widths of the bars and spaces. Such a signal is then decoded according to the specific symbology into a binary representation of the data encoded in the symbol,

and to the alphanumeric characters so represented.

The decoding process in known scanning systems usually works in the following way. The decoder receives the pulse width modulated digital signal from the scanner, and an algorithm implemented in software attempts to decode the scan. If the start and stop characters and the characters between them in the scan were decoded successfully and completely, the decoding process terminates and an indicator of a successful read (such as a green light and/or an audible beep) is provided to the user. Otherwise, the decoder receives the next scan, performs another decode attempt on that scan, and so on, until a completely decoded scan is achieved or no more scans are available.

More sophisticated scanning, described in U.S. Patent 5,235,167, assigned to the common assignee, and incorporated herein by reference, carries out selective scanning of 1-D and 2-D barcodes. Preliminary information, such as the barcode type and size, is preliminarily decoded during an aiming mode of operation when a relatively narrow and visible raster pattern is impinged on the target. Based upon the preliminary information, received by the scanner in the form of light reflected from the target, converted to an electrical signal and decoded, an appropriately sized raster scan pattern is generated. If the barcode pattern is found to be skewed or misaligned with respect to the direction of the raster scanning pattern, the pattern is generated with an orientation in alignment with the barcode.

Aligning the scan pattern to the barcode is awkward, especially for long range scanning. If a barcode is not horizontally positioned on, for example, a container, the user is forced to position the scanner sideways in order to scan the barcode. One possible solution, described in the aforementioned U.S. Patent 5,235,167, is to control the scanner to self-orient the scan pattern to the orientation of the barcode.

Scanning 2-D, or PDF, barcodes with a raster pattern also presents a similar problem. At certain distances, the visibility of a 2-D raster pattern is poorer than that of a single line, and orienting the barcode with the scan lines is not effortless. Assuming the pattern to be amply visible, the user may tend to position the 2-D barcode horizontally under a scan lamp. However, it would be ideal if no aligning is required. For example, a 2-D barcode may have been a photocopy vertically aligned onto a page. Upon scanning, the user may first subconsciously attempt to present the page horizontally, and thus present the barcode vertically. Without ability by the scanner to instantaneously sense barcode orientation, and then position a raster pattern to scan it, the user will be forced to realign the page vertically.

Following alignment of the scan pattern to the barcode, the pattern is then increased in width so as to fully span the length of the barcode, and if the pattern is determined to be a 2-D barcode, the height of the scan pattern is also increased so as to decode all of the barcode rows. However, the rate at which the raster pattern is increased in size is fixed and independent of the size of the barcode or the distance between the hand-held scanner and target. At a common rate of pattern size increase, depending upon the size of the barcode it may require from 0.1 to 2.0 seconds to open the scan pattern and decode the barcode. Distance to the target is another factor. Pattern size is incremented until the entire pattern is decoded. The size of each increment of increase is determined in part by the working range of the scanner. Very long range scanners, usable up to sixty feet, for example, may require smaller increments so that the patterns do not grow too fast at the end of a working range where much of the information, including start and stop codes, concerning attributes of the barcode resides. Hence, it would be desirable to control the rate at which the scan pattern grows to decode the barcode depending upon the characteristics of the barcode itself.

The scanner unit must be compact, energy efficient, and capable of scanning both 1-D and 2-D barcodes. The unit preferably will also be convertible between hand and surface support applications. The scan pattern will preferably be optimized in accordance with whether the unit is in hand held or surface supported modes of operation, whether it is in a presentation type of operation (wherein the indicia are passed under a scan lamp) or a pass through type of operation (supermarket type) and on the type of barcode or other indicia to be read.

Reference will now be made to further aspects of known scanners. A typical optical scanner (for example a bar code scanner) has a light source, preferably a laser light source, and means for directing the laser beam onto a symbol (for example a bar code) to be read. On route to the symbol, the laser beam is generally directed onto, and reflected off, a light reflecting mirror of a scanning component. The scanning component causes oscillation of the mirror, so causing the laser beam repetitively to scan the symbol. Light reflected from the symbol is collected by the scanner and detected by a detector such as a photodiode. Decode circuitry and/or a microprocessor algorithm is provided to enable the reflected light to be decoded, thereby recovering the data which is recorded by the bar code symbol.

Scanners of this general type have been disclosed, for example, in US Patents 4 251 798; 4 360 798; 4 369 361; 4 387 297; 4 593 186; 4 496 831; 4 409 470; 4 808 804; 4 816 661; 4 816 660;

and 4 871 904, all of which patents have been assigned to the same assignee as the present invention, and all of which are hereby incorporated by reference.

In recent years, it has become more common for bar code scanners to have within them a distinct scanner module containing all the necessary mechanical and optical elements needed to create the scanning of the laser beam and to deal with the incoming reflected beam from the bar code that is being scanned. Using a separate scanner module, within the housing of the bar code scanner, facilitates a modular approach to design and manufacture, thereby keeping costs down, improving reliability, and facilitating the transfer of scanning technology to a variety of scanner housings. A typical prior art scanner module is disclosed in US Patent 4 930 848, to Knowles.

There are a large number of known ways of mounting a mirror within the scanning component to cause the necessary scanning motion of the laser beam. Some provide for oscillation in only a single direction, so that the scanning laser beam traces out a single path across the bar code being scanned. Others provide two dimensional scanning patterns, such as for example raster patterns or patterns of greater complexity. Examples of scanning components allowing two dimensional scanning are shown in US Patent 5 280 165, and in European Patent Application 540 781. Both of these are assigned to the same assignee as the present invention, and are hereby incorporated by reference.

As optical scanning systems have become more complex, and as the demand for smaller size and lower power consumption has increased, shock protection for the scanner modules has become more difficult. These highly efficient scan engines, with both resonant and non-resonant scanning elements are difficult to protect because the scanning element must be free to move for scanning but must be protected in the event of a shock (for example if the user drops the bar code scanner within which the scanner module is incorporated). Also, as sizes are reduced manufacturing tolerances begin to have more significant impacts on costs. Furthermore, it becomes more difficult to achieve accurate optical alignment during assembly, and to maintain that optical alignment during the life of the product.

It is a general object of the invention at least to alleviate the problems of the prior art.

It is an additional object to provide a scanner module in which the scanning element is protected against shock.

It is a further object to provide a scanner module of increased compactness.

It is a further object to provide a robust, compact scanner module having reduced manufacturing/assembly costs.

A general object of this invention is to improve aim and shoot capabilities of hand-held barcode scanners. A more particular object is to improve the scan pattern visibility of hand-held barcode scanners during aiming. Another object of the invention is to implement robust scan patterns during decoding, and another is to enable the scanner to automatically orient the scan pattern to the rotational orientation of the symbol. A further object is to transition between aiming and decoding automatically while reading 1-D or 2-D barcodes. Other objects of this invention include miniaturizing the scan mechanism so as to enable the scanner to be conveniently hand-held, and compactly housing the scanner, and providing convertibility between hand-held and surface mount applications while automatically generating scan patterns optimized for the particular application and type of indicia being read.

These and other objects and features of the invention are satisfied, at least in part, by a scanning system operable both in portable and fixed modes for reading barcode symbols comprising means for determining whether operation is in a fixed or portable mode, and means for adapting the scan pattern to an optimized pattern for such mode of operation. Preferably, the scan pattern is also optimized in dependency on the type of indicia being read and whether scanning is carried out in a presentation type (under a scan lamp) or a pass through (supermarket) type reader.

In accordance with a preferred embodiment, a light beam scanner generates a light beam directed toward a symbol to be read and moves the beam along the symbol in an omnidirectional scanning pattern, that is, one wherein the pattern trajectory is not limited to one or a limited number of directions while a symbol is traversed. A light detector receives reflected light from the symbol and generates electrical signals responsive to the reflected light, and the scanning pattern is controlled in response to the electric signals. The scanning pattern may be radially symmetric, a rotating line pattern, or a spiral pattern. The pattern control may vary the diameter or trajectory of the light beam, and more particularly may move the light beam selectively along a first scan path or a second scan path depending on the electrical signals. In preferred embodiments, the first and second scan paths differ from each other by rotation about an axis of rotation, by an increase in scan path envelope diameter, by rotation of the first scan path about an axis of rotation and increase of scan path envelope diameter, or by displacement of the center of rotation of the first scan pattern. Preferably,

the scan pattern is such that the bar code is traversed by at least two scan lines per row of bar patterns during reading.

A particular embodiment of the foregoing includes providing a relatively bright, rosette scanning pattern for enabling a user to aim and direct the beam toward a bar code symbol to be read, scanning the symbol, detecting light reflected from the symbol and generating an electrical signal in response to the reflected light, and modifying the radial diameter of the scan pattern in response to the electrical signal.

Another aspect of the invention provides a light source for generating a light beam directed toward a symbol to be read, and a light detector for receiving light reflected from the symbol and, in response, generating an electrical signal. This signal is converted to data corresponding to a content of the symbol. The light beam is controlled to scan the symbol with a prescribed scan pattern to develop first data, and thereafter increase a dimension of the scan pattern at a rate dependent upon that first data.

Preferably, the scan pattern is increased in dimension at a rate, and to a magnitude, that are determined by the decoded signal, to produce ultimate data corresponding to the symbol.

In accordance with a preferred embodiment, the light beam is controlled to scan a symbol in an aim mode of operation and thereafter in a decode mode. The decode mode may follow the aim mode in response to a second manual operation of a trigger, or may occur automatically. In the aim mode, the light beam scans the symbol with a first, relatively small prescribed scan pattern that is visible to the user and covers only a portion of the symbol. The decode mode of operation scans a portion of the symbol with a second (same or different) prescribed scan pattern, and then incremently increases the size of this second pattern while decoding. Scan patterns found useful for aiming and decoding are spiral, stationary or rotating Lissajous, rotating line and rosette, with the spiral producing the most visible aim pattern and the rotating Lissajous producing the most robust decoding. A stationary or precessing raster pattern is produced for 2-D barcode scanning and decoding.

Although the scan patterns for aiming and decoding may be the same, they preferably are different. In this respect, the symbol is preliminarily analyzed using a rotating Lissajous pattern during the aim mode of operation to determine whether the symbol is one-dimensional or two-dimensional, and, in accordance with another aspect of the invention, the light beam is automatically controlled to describe a stationary or precessing raster scan pattern for decoding if the symbol is two-dimensional. If the scanned symbol is determined to be a one-dimensional symbol, the pattern for aiming and decoding both preferably are a rotating Lissajous. A scan control circuit automatically transitions between the aiming and decoding patterns, such as from Lissajous to raster for 2-D scanning.

In accordance with a further aspect of the invention, the scanner is incorporated within a housing including an approximately square window for enabling the light beam to pass through it. The housing is adapted to be hand-held, and releasably attached to a surface mount base. In a preferred embodiment, the surface mount base enables the housing to rotate about vertical and horizontal axes, and optionally includes a vertical extension to increase the height of the scanner.

Yet another aspect of this invention concerns decoding a barcode that is angularly offset from the horizontal, without prior knowledge by the user, and despite any droop in the scan lines emitted the scanner that is characteristic of some 2-D scanning mechanisms. Advantageously, the light beam is controlled to traverse the symbol with a scan pattern having the form of a raster that precesses among successive frames so as to align with rows of barcode oriented at various angles.

A further aspect of the invention provides system for reading coded indicia, comprising an electro-optical reader within a portable housing having a means for enabling a human operator to hold and aim the reader at indicia to be read. The reader includes a light source for generating a light beam, a light detector for receiving light reflected from the indicia and responsively generating an electrical signal, and means for converting the electrical signal to data representing information content of the indicia. A stationary fixture has a means for supporting the portable housing of the reader when not held by the operator. A scan control means controls the light beam to scan the indicia with different prescribed scan patterns in response to the information content of the indicia and whether the portable housing is separated from or mounted in the fixture.

When the reader is enabled, the scan means controls the light beam to preliminary scan the indicia with a scan pattern, such as a rotating Lissajous, that indexes angularly so as to traverse the indicia along different directions progressively as a function of time. Assume first that the housing is separated from the fixture. When the indicia content corresponds to a 1-D barcode pattern, as determined during preliminary scanning the scan pattern for decoding continues as a rotating Lissajous pattern, in accordance with the preferred embodiment. When the indicia content corresponds to a 2-D barcode pattern, the scan pattern preferably changes to a precessing raster pattern.

If the housing is mounted in the fixture, and the indicia content corresponds to a 1-D barcode pattern, as determine during preliminary scanning the scan pattern for decoding may be a single line or multiple line scan pattern. If the indicia content corresponds to a 2-D barcode pattern, the scan pattern may be a raster pattern. In either case, the scan pattern for decoding is optimized to read the classification of barcode preliminary scanned.

A particularly advantageous "aim and shoot" operation of the scanner, in accordance with the invention, is as follows. The operation comprises first directing a light beam toward a symbol to be read, executing an aim mode of operation by controlling the light beam to scan the symbol with a visible scan pattern in the form of a rotating Lissajous pattern, and then receiving light reflected from the symbol and producing first data identifying an attribute of the symbol including whether the symbol represents a one-dimensional or two-dimensional barcode symbol. The operation then provides executing a decode mode such that (a) if during aiming, the symbol is determined to be a one-dimensional barcode symbol, decoding while scanning using a rotating Lissajous scan pattern to scan the symbol, and (b) if the symbol is determined to be a two-dimensional barcode symbol, decoding while using a raster scan pattern to scan the symbol.

The scanner mechanism, in accordance with a first embodiment, comprises a housing, a source within the housing for emitting a light beam to be reflected from a symbol to be scanned, and a photodetector positioned within the housing for receiving light reflected from the symbol and responsively producing an electrical signal. An optical element is positioned within the housing in a path of the light beam, and a permanent magnet mounted to a support member and produces a magnetic field. An electric coil, mounted with the optical element, is axially displaced from the support member. A plurality of semi-rigid electrically conducting wires interconnect the coil and the support member such that AC drive current applied to the coil through the wires causes the coil to generate an electromagnetic field for interaction with the magnetic field of the permanent magnet to produce oscillatory motions of the optical element.

Another scanning mechanism comprises a housing, a source within the housing for emitting a light beam to be reflected from a symbol to be scanned, a photodetector positioned within the housing for receiving light reflected from the symbol and responsively producing an electrical signal, and an optical scanning element in the housing. The optical scanning element is formed by an optical element positioned in a path of the light beam, and a cylindrical permanent magnet mounted to a support member of magnetically permeable material for producing a magnetic field, the cylindrical magnet having an open end opposing the support member. A cylindrical electric coil is mounted to the support member, surrounded by the permanent magnet and itself surrounding a core of the magnetically permeable material. A flexible membrane is mounted to and spans the open end of the cylindrical permanent magnet, and a metal plate of small mass is attached to the membrane in proximity to the electric coil and the core. An optical element is mounted for pivotal movement, and displaced from but axially aligned with the metal plate, and a coupling element of small mass interconnects the optical element and the metal plate. AC drive current applied to the coil causes the coil to generate an electromagnetic field for interaction with the magnetic field of the permanent magnet to produce oscillatory motions of the optical element with repetitive flexing of the diaphragm.

Another embodiment of the invention provides a housing, a source within the housing for emitting a light beam to be reflected from a symbol to be scanned, and a photodetector positioned within the housing for receiving light reflected from the symbol and responsively producing an electrical signal. An optical scanning element in the housing is formed by a reflector or other optical element positioned in a path of the light beam. An electric coil of cylindrical shape is mounted to a support member and produces a varying magnetic field in response to an AC current, and a permanent magnet is mounted in alignment with a central axis, and adjacent one end, of the coil. The reflector for light emitted from the light source is of a mass substantially less than the mass of the permanent magnet. An arcuate bracket of flexible material interconnects the permanent magnet and the reflector.

A further embodiment of scanner mechanism provides a frame formed of flexible material and having first and second opposed ends, and a pair of parallel, slightly spaced apart wires connected to and maintained taut between the ends of the frame. Mounted to the pair of taut wires approximately centrally between the ends of the bracket, a subassembly includes an optical element for directing the light beam, and a permanent magnet coupled to the optical element and developing a magnetic field. An electromagnetic coil receives AC drive current to generate an electromagnetic field for interaction with the magnetic field of the permanent magnet and induce oscillatory motion in a first scanning direction to the optical element.

Still other objects and advantages of the present invention will become readily apparent to those skilled in this art from the following detailed description, wherein only the preferred embodi-

ment of the invention is shown and described, simply by way of illustration of the best mode contemplated of carrying out the invention. As will be realized, the invention is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the invention. Accordingly, the drawing and description are to be regarded as illustrative in nature, and not as restrictive.

According to an aspect of the present invention there is provided a scan module for use in a scanner for reading indicia having parts of differing light reflectivity, the scan module comprising:

a) a frame;

b) a scanning component mounted to the frame for oscillatory motion, the scanning component including an optical element for directing light in a scanning pattern across an indicia to be read, the scanning component having an aperture therein;

c) an anti-shock member, passing through the aperture in the scanning component, the anti-shock member being smaller in cross section than the size of the aperture, thereby providing clearance for the scanning component to oscillate in use, but preventing excessive movement of the scanning component with respect to the frame in the event that the module is subjected to a mechanical shock.

According to a further aspect of the invention there is providing a method of assembling a scan module for use in a scanner for reading indicia having parts of differing reflectivity, the scan module comprising: a frame; a scanning component to be mounted to the frame for oscillatory motion, the scanning component including an optical element for directing light in a scanning pattern across an indicia to be read, the scanning component having an aperture therein; and an anti-shock pin having a first head portion, a second portion, and a waist portion having a smaller cross section than the first and second head portions; the method comprising:

a) positioning the scanning component adjacent to the frame;

b) partially inserting the pin in to the frame so that the second head portion passes through the aperture and extends from the aperture in to a correspondingly-shaped bore in the frame, thereby aligning the scanning component with respect to the frame;

c) securing the scanning component to the frame;

d) continuing insertion of the pin in to the frame so that the waist portion of the pin becomes located within the aperture, thereby providing clearance for the scanning component to oscillate in use, but preventing excessive movement of the scanning component with respect to the frame in the event that the module is subjected to a mechanical shock.

According to a further aspect of the invention there is provided a scan module for use in a scanner for reading indicia having parts of differing light reflectivity, the scan module comprising:

a) a frame;

b) a scanning component comprising a bracket mounted to the frame by flexible support means for oscillatory motion, the bracket carrying an optical element for directing light in a scanning pattern across an indicia to be read;

c) an electromagnetic coil mounted to the frame;

d) magnet means secured to the bracket adjacent the coil;

and

e) the bracket further including a counterweight portion balancing the mass of the optical element at the flexible support means, the counterweight portion at least partially overlying the coil.

According to yet a further aspect of the invention there is provided a scan module for use in a scanner for reading indicia having parts of differing light reflectivity, the scan module comprising:

a) a frame;

b) a scanning component comprising a main bracket mounted to the frame by flexible support means for oscillatory motion, the main bracket carrying an optical element for directing light in a scanning pattern across an indica to be read, the main bracket having an aperture therein;

c) an electromagnetic coil mounted to the frame;

d) magnet means, secured to the bracket adjacent to the coil;

e) the bracket further including a counterweight portion balancing the mass of the optical element at the flexible support means, the counterweight portion at least partially overlying the coil;

and

f) an anti-shock member passing through the aperture in the main bracket, the member being smaller in cross section than the size of the aperture, thereby providing clearance for the scanning component to oscillate in use, but preventing excessive movement of the scanning component with respect to the claim in the event that the module is subjected to a mechanical shock.

Preferably, the scanning component comprises a main bracket (for example of a beryllium copper alloy) which includes a pair of hanging brackets by which the main bracket is secured to the frame. Each hanging bracket has attached to it a thin strip of a polyester film, the strip being secured at one

end to the hanging bracket and at the other end to the frame. The main bracket therefore hangs from the frame on the strips. The strips can flex, allowing the main bracket to oscillate.

The main bracket desirably carries an optical element, such as a mirror, for directing light shone on to it in a scanning pattern across the indicia to be read. The mirror may be secured to the main bracket by a further flexure, allowing the mirror to oscillate independently of the main bracket. If the flexure supporting the mirror and the strips are arranged to flex in mutually perpendicular directions, two dimensional scanning patterns (such as raster patterns) can be produced.

The strips may be protected from mechanical shock by first and second anti-shock pins which pass through apertures in the hanging brackets. The diameter of the central portions of the pins is slightly smaller than the diameter of the apertures, thereby allowing the main bracket to oscillate in use. However, if a shock is applied to the scan module, the pins prevent excessive movement of the main bracket, and hence prevent over-stressing of the strips.

Each anti-shock pin may include an enlarged head portion, which is of substantially the same size and shape in cross section as the aperture in the respective hanging bracket. This allows the main bracket to be accurately positioned with respect to the frame during assembly of the scan module, when the pin is in a partially-inserted position. Once the position has been accurately determined, the main bracket may be secured to the frame, and the pins fully inserted.

The invention extends to any one or more of the following clauses:

A scanning system operable both in portable and fixed modes for reading barcode symbols, comprising:

means for determining whether operation is in a fixed or portable mode; and

means for adapting the scan pattern to an optimized pattern for such mode of operation.

The system of 1, including means for detecting the mode in which mode said system is operating, and wherein said scan means is responsive to said detecting means for controlling the light beam to traverse the indicia with a scan pattern optimized for the detected mode.

The system of 1, wherein said scan means is further responsive to said information content of said indicia being read for controlling the light beam to traverse the indicia with a scan pattern also optimized for reading the indicia.

The system of 3, wherein the scanning means produces a self-aligning raster pattern when the system is operating in the fixed mode and the indicia comprise a 2-D barcode.

The system of 3, wherein the scanning means produces a Lissajous raster pattern when the system is operating in the fixed mode and the indicia comprise a 1-D barcode.

The system of 3, wherein the scanning means produces a single line pattern when the system is operating in the portable mode and the indicia comprise a 1-D barcode.

The system of 3, wherein the scanning means produces an omnidirectional pattern when the system is operating in the portable mode and the indicia comprise a 1-D barcode.

The system of 3, wherein the scanning means produces a stationary raster pattern when the system is operating in the portable mode and the indicia comprise a 2-D barcode.

A system for reading coded indicia, comprising:

an electro-optical reader within a portable housing having a means for enabling a human operator to hold and aim the reader at indicia to be read, the reader including a light source for generating a light beam, a light detector for receiving light reflected from said indicia and in response generating an electrical signal, and means for converting said electrical signal to data representing information content of said indicia;

a stationary fixture having a means for supporting the portable housing of the reader when not held by the operator; and

scan control means for controlling the light beam to scan the indicia with a first scan pattern for reading the coded indicia independently of pattern orientation when the portable housing is mounted in said fixture and a second scan pattern optimized for reading a prescribed classification of coded indicia when the portable housing is separated from said fixture.

The system of 8, wherein said first scan pattern comprises an omnidirectional scan pattern.

The system of 8, wherein said first scan pattern comprises a Lissajous pattern.

The system of 10, wherein said Lissajous pattern is rotating.

The system of 8, wherein said first scan pattern comprises a rotating scan pattern.

The system of 8, wherein said first scan pattern comprises a precessing scan pattern.

The system of 13, wherein said scan pattern is a precessing raster pattern.

The system of 8, wherein said second scan pattern comprises a line pattern.

The system of 8, wherein said second scan pattern comprises a star pattern.

The system of 8, including means for detecting whether said housing is mounted in said fixture, and wherein said scan means is responsive to said detecting means for controlling the light beam to

traverse the indicia with a particular scan pattern.

The system of 17, wherein said scan means is further responsive to said information content of said indicia for controlling the light beam to traverse the indicia with a particular scan pattern.

A system for reading coded indicia, comprising:

an electro-optical reader within a portable housing having a means for enabling a human operator to hold and aim the reader at indicia to be read, the reader including a light source for generating a light beam, a light detector for receiving light reflected from said indicia and responsively generating an electrical signal, and means for converting said electrical signal to data representing information content of said indicia;

a stationary fixture having a means for supporting the portable housing of the reader when not held by the operator; and

scan control means for controlling the light beam to scan the indicia with different prescribed scan patterns in response to the information content of the indicia and whether the portable housing is separated from or mounted in said fixture.

The system of 19, wherein, when said housing is separated from said fixture, said scan means controls the light beam to scan the indicia with a scan pattern that indexes angularly so as to traverse said indicia along different directions progressively as a function of time.

The system of 20, wherein, when said indicia content corresponds to a 1-D barcode pattern, said scan pattern is a rotating Lissajous pattern.

The system of 20, wherein, when said indicia content corresponds to a 2-D barcode pattern, said scan pattern is a precessing raster pattern.

The system of 19, wherein, when said housing is mounted in said fixture, said scan means controls the light beam to scan the indicia with a linear scan pattern.

The system of 23, wherein, when said indicia content corresponds to a 1-D barcode pattern, said scan pattern is a single line scan pattern.

The system of 23, wherein, when said indicia content corresponds to a 2-D barcode pattern, said scan pattern is a raster pattern.

A device for reading barcode symbols, or the like, comprising:

a light source for generating a light beam and directing the beam toward a symbol to be read;

a light detector for receiving light reflected from said symbol and, in response, generating an electrical signal;

means for converting said electrical signal to data representing the information content of said barcode symbol; and

scan control means for controlling the light beam to scan the symbol with a prescribed scan pattern to develop control information, and thereafter to increase a dimension of the scan pattern at a rate dependent upon said control information.

The device of 27, wherein said scan control means includes means for decoding said electrical signal while increasing said scan pattern dimension to produce additional data corresponding to said symbol.

The device of 27, wherein said scan control means includes means for increasing said scan pattern dimension to a prescribed maximum dimension dependent upon said control information.

The device of 28, wherein said scan control means includes means for executing (a) an aim mode of operation wherein said light beam is controlled to scan said symbol with a first scan pattern that is visible to the user and covers only a portion of said symbol, and (b) a decode mode of operation wherein said light beam is controlled to scan a portion of said symbol with a second prescribed scan pattern and thereafter to successively increment the size of said second scan pattern while decoding said symbol.

The device of 30, wherein said first prescribed scan pattern is selected from the group consisting of the following patterns: spiral, stationary or rotating Lissajous, rotating line and rosette.

The device of 30, wherein said second prescribed scan pattern is a stationary or precessing raster pattern.

The device of 31, wherein said scan control means further includes means responsive to data produced during said aim mode of operation for determining whether the symbol is a one-dimensional or two-dimensional barcode, and wherein said second prescribed scan pattern is controlled to be a stationary or precessing raster scan pattern if said symbol is determined to be a two-dimensional barcode.

The device of 33, wherein said first prescribed scan pattern is other than a raster, and said scan control means includes circuit means for transitioning said scan pattern from said first prescribed scan pattern to a stationary or precessing raster.

The device of 27, incorporated within a housing including an approximately square window for enabling said light beam to pass therethrough.

The device of 35, wherein said housing is adapted to be hand-held, and means for releasably attaching said housing to a surface mount base.

The device of 36, wherein said surface mount base enables said housing to rotate about at least one of a vertical axis and a horizontal axis.

The device of 36, wherein said surface mount base includes a vertical extension to increase height of said housing.

The device of 30, including means for detecting angular orientation of said barcode symbol dur-

ing said aim mode of operation, and responsively orienting said second prescribed scan pattern during said decode mode of operation.

The device of 39, wherein when said symbol is determined to be a one-dimensional barcode, said first and second prescribed patterns are controlled to be a rotating Lissajous.

The device of 39, wherein when said symbol is determined to be a two-dimensional barcode, said first and second prescribed patterns are controlled to be rotating Lissajous and raster scan patterns, respectively.

A method of reading barcode symbols, comprising the steps of:

directing a light beam toward a symbol to be read;

controlling said light beam to scan said symbol with a prescribed scan pattern of a first prescribed dimension;

receiving light reflected from said symbol, and in response, generating an electrical signal;

producing first data corresponding to said electrical signal; and

increasing the dimension of said scan pattern at a rate dependent upon said first data.

The method of 42, wherein said scan pattern is increased to a second prescribed maximum dimension dependent upon said first data.

The method of 43, including the step of decoding said symbol while increasing said scan pattern dimension.

The method of 43, including executing (a) an aim mode of operation by controlling said light beam to scan said symbol with a first scan pattern that is visible to the user and covers only a portion of said symbol, and (b) a decode mode of operation by controlling said light beam to scan a portion of said symbol with a second prescribed scan pattern and thereafter to successively increment the size of said second scan pattern while decoding said symbol.

The method of 45, wherein said first prescribed scan pattern is selected from the group consisting of the following patterns: spiral, stationary or rotating Lissajous, rotating line and rosette.

The method of 46, wherein said second prescribed scan pattern is a stationary or precessing raster pattern.

The method of 31, including the step of responding to data produced during said aim mode of operation by determining whether the symbol is a one-dimensional or two-dimensional barcode symbol, and controlling said second prescribed scan pattern to be a stationary or precessing raster if said symbol is determined to be a two-dimensional barcode.

The method of 48, wherein when said first prescribed scan pattern is other than a stationary raster or precessing scan pattern, and including the additional step of transitioning said scan pattern from said first prescribed scan pattern to a stationary or precessing raster scan pattern.

A method of reading barcode symbols, comprising the steps of:

directing a light beam toward a symbol to be read;

executing an aim mode of operation by controlling said light beam to scan said symbol with a visible scan pattern that is relatively small compared to the symbol;

receiving light reflected from said symbol, and producing first data identifying an attribute of said symbol; and

executing a decode mode of operation by producing second data corresponding to the symbol while increasing a dimension of said scan pattern at a rate and to a size dependent upon said first data.

The method of 50, wherein said scan patterns in said aim and decode modes of operation are of different configurations.

The method of 50, including the step of responding to data produced during said aim mode of operation by determining whether the symbol is a one-dimensional or two-dimensional barcode, and controlling said scan pattern to be a stationary or precessing raster scan pattern during said decode mode of operation if said symbol is determined to be a two-dimensional barcode symbol.

The method of 50, including the step of responding to data produced during said aim mode of operation by determining rotational orientation of the barcode, and responsively controlling said scan pattern to have a proper alignment to said barcode during said decode mode of operation.

A device for reading barcode symbols, or the like, comprising:

a light source for generating a light beam and directing the beam toward a symbol to be read;

scan control means for controlling the light beam to scan the symbol with a scan pattern having the form of a raster that precesses among successive frames;

a light detector for receiving light reflected from said symbol and, in response, generating an electrical signal; and

means for converting said electrical signal into data corresponding to content of said symbol.

A method of reading barcode symbols, or the like, comprising the steps of:

generating a light beam and directing the beam toward a symbol to be read;

controlling the light beam to traverse the symbol with a scan pattern having the form of a raster that precesses among successive frames so as to be capable of decoding one-dimensional barcodes

of varying horizontal orientation and of decoding two-dimensional barcodes despite any arcuate non-linearity (droop) of the raster pattern;

receiving light reflected from said symbol and responsively producing an electrical signal; and

converting said electrical signal into data corresponding to content of said symbol.

A device for reading barcode symbols, or the like, comprising:

a light source for generating a light beam and directing the beam toward a symbol to be read;

scan control means for controlling the light beam to scan the symbol with a rotating Lissajous scan pattern;

a light detector for receiving light reflected from said symbol and, in response, generating an electrical signal; and

means for converting said electrical signal into first data corresponding to an attribute of said barcode symbol;

said scan control means including further means for converting the rotating Lissajous scan pattern to a raster scan pattern depending upon said barcode symbol attribute.

The device of 56, wherein said symbol attribute defines whether the symbol is a one-dimensional or two-dimensional barcode, and said scan control means converts said rotating Lissajous scan pattern to a raster scan pattern only if said symbol is a two-dimensional scan pattern.

The device of 57, wherein the attribute defines symbol size or type, and said scan control means further increases the size of said raster scan pattern to a maximum size determined by the attribute.

The device of 57, wherein said scan control means includes means for determining rotational orientation of said symbol, and responsively controlling rotational alignment of said raster scan pattern.

The device of 59, incorporated in a housing including an approximately square window for enabling said light beam to pass therethrough.

The device of 60, wherein said housing is adapted to be hand-held, and means for releasably attaching said housing to a surface mount base.

The device of 61, wherein said surface mount base enables said housing to rotate about at lease one of a vertical axis and horizontal axis.

The device of 61, wherein said surface mount base includes a vertical extension to increase height of said housing.

A method of reading barcode symbols, comprising the steps of:

directing a light beam toward a symbol to be read;

executing an aim mode of operation by controlling said light beam to scan said symbol with a visible scan pattern in the form of a rotating Lissajous pattern;

receiving light reflected from said symbol, and producing first data identifying an attribute of said symbol including whether said symbol represents a one-dimensional barcode symbol or a two-dimensional barcode symbol; and

executing a decode mode of operation such that

(a) if during said aim mode of operation, said symbol is determined to be a one-dimensional barcode, decoding while scanning using a rotating Lissajous scan pattern to scan said symbol, and

(b) if during said aim mode of operation said symbol is determined to be a two-dimensional barcode, decoding while using a raster scan pattern to scan said symbol.

The method of 64, wherein, during (b) the raster scan pattern is increased in size during decoding.

The method of 65, wherein said raster scan pattern is increased in size at a rate that depends on symbol attribute.

The method of 64, wherein, during (b), the raster scan pattern precesses.

The method of 64, further including determining rotational orientation of said symbol during the aim mode of operation, and responsively controlling rotational alignment of said raster scan during the decode mode of operation.

An optical scanning assembly, comprising:

a housing;

a source within said housing for emitting a light beam to be reflected from a symbol to be scanned;

a photodetector positioned within said housing for receiving light reflected from said symbol and responsively producing an electrical signal;

an optical element positioned within the housing in a path of said light beam;

a permanent magnet mounted to a support member and producing a magnetic field;

an electric coil mounted with said optical element and axially displaced from said support member; and

a plurality of semi-rigid electrically conducting wires interconnecting said coil and said support member such that AC drive current applied to said coil through said wires causes said coil to generate an electromagnetic field for interaction with the magnetic field of said permanent magnet to produce oscillatory motions of said optical element.

The assembly of 69, wherein said light source is mounted to said support member on an optical axis of said optical element.

The assembly of 69, wherein said semi-rigid wires are made of a phosphor-bronze alloy.

The assembly of 70, wherein said permanent magnet is in the form of a ring having a central opening aligned with said light source, and serves as an aperture stop for said beam.

The assembly of 72, wherein said permanent magnet is poled longitudinally.

The assembly of 69, wherein said optical element comprises a lens.

The assembly of 74, wherein said permanent magnet is multiply poled circumferentially, and wherein rotation of said ring about said poles controls focus of the beam passing through said lens.

The assembly of 75, wherein said coil is wired such that current passing therethrough oscillates said lens to describe a prescribed scan pattern and selectively rotates said lens so as to adjust the axial position, and hence, focussing, of said lens.

An optical scanning assembly, comprising:

a housing;

a source within said housing for emitting a light beam to be reflected from a symbol to be scanned;

a photodetector positioned within said housing for receiving light reflected from said symbol and responsively producing an electrical signal; and

an optical scanning element in said housing and formed by the following:

an optical element positioned in a path of said light beam,

a cylindrical permanent magnet mounted to a support member of magnetically permeable material for producing a magnetic field, said cylindrical magnet having an open end opposing said support member,

a cylindrical electric coil mounted to said support member, surrounded by said permanent magnet and itself surrounding a core of said magnetically permeable material,

a flexible membrane mounted to and spanning the open end of said cylindrical permanent magnet,

a metal plate of small mass attached to said membrane in proximity to said electric coil and said core,

an optical element mounted for pivotal movement, and displaced from but axially aligned with said metal plate, and

a coupling element of small mass interconnecting said optical element and said metal plate;

whereby AC drive current applied to said coil causes said coil to generate an electromagnetic field for interaction with the magnetic field of said permanent magnet to produce oscillatory motions of said optical element with repetitive flexing of said diaphragm.

The assembly of 77, wherein said coupling element is in the form of a thin rod with ends thereof coupled to said plate and element.

The assembly of 78, wherein said rod is made of Mylar film.

The assembly of 77, wherein said optical element is supported on an arm that is pivotably mounted with respect to said permanent magnet.

The assembly of 80, wherein said arm is made of Mylar film.

The assembly of 81, wherein said support member is positioned within a cup-shaped casing, and said arm is pivotably mounted to said casing.

The assembly of 77, wherein said optical element comprises a reflector.

An optical scanning assembly, comprising:

a housing;

a source within said housing for emitting a light beam to be reflected from a symbol to be scanned;

a photodetector positioned within said housing for receiving light reflected from said symbol and responsively producing an electrical signal; and

an optical scanning element in said housing and formed by the following:

an optical element positioned in a path of said light beam,

an electric coil of cylindrical shape mounted to a support member and producing a varying magnetic field in response to an AC current,

a permanent magnet mounted in alignment with a central axis, and adjacent one end, of said coil,

a reflector for light emitted from said light source and of mass substantially less than the mass of said permanent magnet, and

an arcuate bracket of flexible material interconnecting said permanent magnet and said reflector.

The assembly of 84, including a collector for directing light reflected said symbol to said

The assembly of 85, wherein said collector is positioned between said light source and said reflector and includes an opening for passage of light emitted by said source.

The assembly of 84, wherein said light source is position within said housing such that light emitted by said source is perpendicular to an axis of rotation of said reflector.

An optical scanner module for directing a light beam in a pattern to scan a symbol, comprising:

a frame formed of flexible material and having first and second opposed ends;

a pair of parallel, slightly spaced apart wires connected to and maintained taut between the ends of said frame;

mounted to said pair of taut wires approximately centrally between the ends of said bracket, a subassembly including an optical element for directing the light beam, and a permanent magnet coupled to said optical element and developing a magnetic field; and

an electromagnetic coil for receiving AC drive current to generate an electromagnetic field for interaction with the magnetic field of said perma-

nent magnet to produce oscillatory motion of said optical element in a first scanning direction.

The module of 88, wherein said optical element is clamped to said taut wire pair.

The module of 88, including a motor for oscillating said optical element in a second scanning direction orthogonal to the first scanning direction.

The module of 90, wherein speed of oscillation of said optical element in the first scanning direction by said motor is greater than speed of

A bar code reader, comprising:

a light beam scanner generating a light beam directed toward a symbol to be read and moving said light beam along said symbol in an omnidirectional scanning pattern;

a light detector receiving reflected light from said symbol and generating electrical signals responsive to said reflected light; and

means for controlling said scanning pattern in response to said electric signals.

The bar code reader of 92, wherein said scanning pattern is radially symmetric.

The bar code reader of 92, wherein said scanning pattern is a rotating line pattern.

The bar code reader of 92, wherein said scanning pattern is a spiral pattern.

The bar code reader of 92, wherein said means for controlling varies the trajectory of said light beam in response to said electrical signals.

The bar code reader of 92, wherein said means for controlling varies the diameter of said scan pattern in response to said electrical signals.

The bar code reader of 92, wherein said light beam scanner moves said light beam selectively on a first scan path or on a second scan path depending on said electrical signals.

The bar code reader of 98, wherein said first and second scan paths differ from each other by rotation about an axis of rotation.

The bar code reader of 98, wherein said second scan path differs from said first scan path by an increase in scan path envelope diameter.

The bar code reader of 98, wherein said second scan path differs from said first scan path by rotation of the first scan path about an axis of rotation and increase of scan path envelope diameter.

The bar code reader of 98, wherein said second scan path differs from said first scan path by displacement of the center of rotation of said first scan pattern.

A method of scanning bar code symbols or the like, comprising the steps of:

providing a relatively bright, rosette scanning pattern for enabling a user to aim and direct the beam toward a bar code symbol to be read;

scanning said symbol;

detecting light reflected from the symbol and generating an electrical signal in response to said reflected light; and

modifying the radial diameter of said scan pattern in response to said electrical signal.

A system for reading bar code symbols or the like, comprising:

scanning means for generating a laser beam directed toward a target and producing a first scanning pattern

that enables a user to manually aim and direct the beam to the location desired by the user and a relatively larger second scanning pattern in the form of a Lissajous pattern that sweeps an entire symbol to be read,

means for changing the scanning pattern produced by said scanning means from said first scanning pattern to said second scanning pattern; and

detection means for receiving reflected light from a symbol being read to produce an electrical signal corresponding to data represented by said symbol.

The system of 104, wherein said scanning means includes a semiconductor laser light source to produce said laser beam, and further comprising a housing for manual support having an exit port, wherein said scanning means and said detection means are located in said housing, and said housing includes a handle of a configuration enabling the user to manually aim and direct the laser beam to the target.

The system of 105, further comprising manually actuatable trigger means on said housing for initiating said first scanning pattern, and indicator means to inform the user that the housing is positioned in the correct working range for reading bar code symbols.

The system of 106, wherein said trigger means includes a multi-purpose trigger operatively connected to said scanning means to select between the first scanning pattern and the relatively larger second scanning pattern.

A system for reading bar code symbols or the like, comprising;

scanning means for generating a laser beam directed toward a target and producing a first omnidirectional scanning pattern for a first period of time and subsequently an angularly offset second omnidirectional scanning pattern that sweeps the entire height of a symbol to be read;

means for changing the scanning pattern from said first to said second pattern; and

detection means for receiving reflected light from said symbol to produce electrical signals corresponding to data represented by said symbol.

A method for reading bar code symbols or the like, comprising the steps of:

generating a laser beams directed toward a

target and producing a first scanning pattern that enables the user to manually aim and direct the beam to the location desired by the user and a relatively larger second scanning pattern in the form of an omnidirectional pattern that sweeps an entire symbol to be read;

changing from said first scanning pattern to said second scanning pattern; and

receiving reflected light from said symbol to produce an electrical signal corresponding to data represented by said symbol.

A method for reading bar code symbols or the like, comprising the steps of generating a laser beam directed toward a target and producing a first scanning pattern that has a reflectivity on the target that enables a user to manually aim and direct the beam to a desired location on the target, generating a sequence of different subsequent scanning patterns that each are rotationally offset with respect to the preceding scanning pattern, including a scanning pattern that sweeps the entire symbol to be read, and receiving reflected light from the symbol to produce an electrical signal corresponding to data represented by said symbol.

The method of 110, further comprising the step of actuating a multipurpose trigger to select between the first scanning pattern and a subsequent scanning pattern.

The method of 110, wherein said target includes a bar code symbol with at least two rows of bar patterns and one of said subsequent scanning patterns covers the entire symbol with at least two scan lines per row of bar patterns during reading.

A bar code reader, comprising:

a light beam scanner generating a light beam directed toward a symbol to be read and moving said light beam along said symbol in a prescribed line scanning pattern;

a light detector receiving reflected light from said symbol and generating electrical signals responsive to said reflected light; and

means for controlling the angular orientation of said scanning pattern with respect to a center of rotation thereof in response to said electrical signals.

The bar code reader of 113, wherein said scanner changes the scan path of said light beam from a first scan path to a second and subsequent scan paths in response to said electrical signals so as to create a rotating spiral scan pattern.

The bar code reader of 114, wherein the change from said first scan to said second scan path is rotation of the light beam scanning pattern about an axis of rotation.

The bar code reader of 114, wherein the change from said first scan path to said second scan path further comprises an increase in the diameter of the envelope of the scan pattern.

The bar code reader of 114, wherein the change from said first scan path to said second scan path is rotation about an axis of rotation and an increase in envelope diameter of the scan pattern.

The bar code reader of 114, wherein the change from said first scan path to said second scan path is displacement of the center of rotation of the scan pattern.

The bar code reader of 114, wherein the change from first scan path to said second scan path comprises change to a Lissajous pattern.

The system of 3, wherein the scan pattern is further optimized selectively for presentation and pass through modes of operation.

The invention further extends to the following clauses:

A scan module for use in a scanner for reading indicia having parts of differing light reflectivity, the scan module comprising:

a) a frame;

b) a scanning component mounted to the frame for oscillatory motion, the scanning component including an optical element for directing light in a scanning pattern across an indicia to be read, the scanning component having an aperture therein;

c) an anti-shock member, passing through the aperture in the scanning component, the anti-shock member being smaller in cross section than the size of the aperture, thereby providing clearance for the scanning component to oscillate in use, but preventing excessive movement of the scanning component with respect to the frame in the event that the module is subjected to a mechanical shock.

A scan module as 1 wherein the anti-shock member is a pin having a first head portion, a second head portion, and a waist portion having a smaller cross section than the first and second head portions, the waist portion being located within the aperture during normal operation of the scan module.

A scan module as 2 wherein the first head portion carries an external screw thread which is arranged to be screwed in to a bore in the frame.

A scan module as 2 wherein the second portion is arranged to be received within a correspondingly-sized bore within the frame.

A scan module as 2 wherein the cross sectional size and shape of the second head portion corresponds with the size and shape of the aperture.

A scan module as 5 wherein the second head portion is of such a length that the pin may be positioned with the second head portion contained within the aperture and extending from the aperture in to a correspondingly-sized bore within the frame,

thereby locating the scanning component with respect to the frame.

A scan module as 3 wherein the first head portion is substantially flush with the frame when the pin is in a position for normal operation of the scan module.

A scan module as 2 wherein the pin extends across a cut out portion of the frame, the aperture being in a portion of the scanning component which extends in to the said cut out portion.

A scan module as 8 wherein the said portion of the scanning component comprises a hanging bracket.

A scan module as 9 wherein the hanging bracket is supported from the frame by a flexure member.

A scan module as 10 wherein the flexure member comprises a polyester material film.

A scan module as 1 wherein the aperture is in a portion of the scanning component comprising a hanging bracket.

A scan module as 12 wherein the hanging bracket is supported from the frame by a flexure member.

A scan module as 13 wherein the flexure member comprises a polyester material film.

A scan module as 1 wherein the scanning component is supported from the frame by a flexure member, the scanning component further including counterweight means balancing the mass of the optical element at the flexure member.

A scan module as 15 further including an electromagnetic coil mounted to the frame, the counterweight means at least partially overlying the coil.

A scan module as 1 wherein the scanning component is supported from the frame by a flexure member, and the optical element is supported from the scanning component by a further flexure member, the flexure member and the further flexure member being arranged to flex in mutually perpendicular directions.

A scan module as 1 including first and second anti-shock members, the first anti-shock member being adjacent a first side of the frame, and the second anti-shock member being adjacent a second side of the frame.

A scan module as 1 wherein the anti-shock member has a longitudinal axis, the movement of the scanning component at the aperture, during oscillation, being substantially perpendicular to the said axis.

A scan module as 1 wherein the anti-shock member comprises a pin.

A method of assembling a scan module for use in a scanner for reading indicia having parts of differing reflectivity, the scan module comprising: a frame; a scanning component to be mounted to the frame for oscillatory motion, the scanning component including an optical element for directing light in a scanning pattern across an indicia to be read, the scanning component having an aperture therein; and an anti-shock pin having a first head portion, a second portion, and a waist portion having a smaller cross section than the first and second head portions; the method comprising:

a) positioning the scanning component adjacent to the frame;

b) partially inserting the pin in to the frame so that the second head portion passes through the aperture and extends from the aperture in to a correspondingly-shaped bore in the frame, thereby aligning the scanning component with respect to the frame;

c) securing the scanning component to the frame;

d) continuing insertion of the pin in to the frame so that the waist portion of the pin becomes located within the aperture, thereby providing clearance for the scanning component to oscillate in use, but preventing excessive movement of the scanning component with respect to the frame in the event that the module is subjected to a mechanical shock.

A method as 21 wherein the first head portion of the pin is threaded, and is received within a corresponding threaded bore within the frame.

A method as 22 wherein the final location of the pin, for normal operation of the scan module, is defined by a position in which the first head portion of the pin lies flush with the frame.

A scan module for use in a scanner for reading indicia having parts of differing light reflectivity, the scan module comprising:

a) a frame;

b) a scanning component comprising a bracket mounted to the frame by flexible support means for oscillatory motion, the bracket carrying an optical element for directing light in a scanning pattern across an indicia to be read;

c) an electromagnetic coil mounted to the frame;

d) magnet means secured to the bracket adjacent the coil;

and

e) the bracket further including a counterweight portion balancing the mass of the optical element at the flexible support means, the counterweight portion at least partially overlying the coil.

A scan module as 4 wherein the frame comprises a first side portion, a second side portion, and a rear portion connecting the first and second side portions, the electromagnetic coil being mounted between the side portions.

A scan module as 25 including an optical collector element mounted to the first side.

A scan module as 25 including a photodetector unit mounted to the second side.

A scan module as 25 wherein the first and second sides have respective cut out portions, within which are received respective hanging brackets of the main bracket.

A scan module as 28 wherein the hanging brackets are mounted to the frame by respective flexure members.

A scan module 29 wherein the flexure members are polyester material films.

A scan module as 24 including an anti-shock member passing through an aperture in the main bracket, the anti-shock member being smaller in cross section than the size of the aperture, thereby providing clearance for the scanning component to oscillate in use, but preventing excessive movement of the scanning component with respect to the frame in the event that the module is subjected to a mechanical shock.

A scan module as 31 wherein the anti-shock member comprises a pin.

A scan module as 32 wherein the pin has a first head portion, a second portion, and a waist portion having a smaller cross section than the first and second head portions, the waist portion being located within the aperture during normal operation of the scan module.

A scan module as 33 wherein the first head portion carries an external screw thread which is arranged to be screwed in to a bore in the frame.

A scan module as 33 wherein the head portion is arranged to be received within a correspondingly-sized bore within the frame.

A scan module as 33 wherein the cross sectional size and shape of the second head portion corresponds with the size and shape of the aperture.

A scan module as 36 wherein the second head portion is of such a length that the pin may be positioned with the second head portion contained within the aperture and extending from the aperture in to a correspondingly-sized bore within the frame, thereby locating the scanning component with respect to the frame.

A scan module as 34 wherein the first head portion is substantially flush with the frame when the pin is in a position for normal operation of the scan module.

a scan module as 33 wherein the pin extends across a cut out portion of the frame, the aperture being in a portion of the scanning component which extends in to the said cut out portion.

A scan module as 24 wherein the optical element is supported from the main bracket by a further flexible support means, the flexible support means and the further flexible support means being arranged to flex in mutually perpendicular directions.

A scan module for use in a scanner for reading indicia having parts of differing light reflectivity, the scan module comprising:

a) a frame;

b) a scanning component comprising a main bracket mounted to the frame by flexible support means for oscillatory motion, the main bracket carrying an optical element for directing light in a scanning pattern across an indica to be read, the main bracket having an aperture therein;

c) an electromagnetic coil mounted to the frame;

d) magnet means, secured to the bracket adjacent to the coil;

e) the bracket further including a counterweight portion balancing the mass of the optical element at the flexible support means, the counterweight portion at least partially overlying the coil;

and

f) an anti-shock member passing through the aperture in the main bracket, the member being smaller in cross section than the size of the aperture, thereby providing clearance for the scanning component to oscillate in use, but preventing excessive movement of the scanning component with respect to the claim in the event that the module is subjected to a mechanical shock.

The invention may be carried into practice in a number of ways, and one specific embodiment will now be described, by way of example, with reference to the accompanying drawings. The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The preferred features of the invention, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description, when read in conjunction with the drawings.

Figure 1A is a perspective view of a "palmheld" scanner, in accordance with one aspect of the invention; and Figure 1B is a side view of the scanner in cross-section.

Figure 2A shows raster scanning of a 1-D barcode pattern; and Figure 2B shows scanning of a 2-D, or PDF, barcode pattern.

Figure 3A shows a relatively small pattern in scanning a portion of a 1-D barcode for aiming; and Figure 3B depicts expansion of the scan pattern to decode the entire barcode.

Figure 4A shows a 2-D barcode, scanned by a relatively small, rotating Lissajous pattern for aiming; in Figure 4B, the pattern has transitioned to a raster pattern suitable for 2-D barcode decoding; and in Figure 4C, the raster is enlarged to decode

the complete barcode.

Figures 5A and 5B show rosette patterns of different density for aiming; Figure 5C shows a spiral pattern and Figure 5D shows a stationary Lissajous pattern; and Figure 5E shows a rotating line pattern for aiming with automatic scan alignment.

Figure 6 shows a rotating Lissajous pattern for aiming on and decoding 1-D barcodes.

Figure 7 shows a precessing raster scan pattern for decoding 2-D barcodes of various orientations.

Figure 8 is a simplified block diagram of circuitry for producing aim and rotating line scan patterns.

Figure 9A depicts a raster pattern scanning a 2-D barcode; in Figure 9B, the scan pattern is horizontally misoriented with respect to the barcode; and in Figure 9C, the scan pattern contains a degree of droop. Figures 9D-9F present the same scan patterns to a 1-D barcode.

Figures 10A and 10B depict DBP data streams and signal intervals for two different barcode orientations.

Figure 11 describes methodology for automatic barcode alignment.

Figure 12 is a simplified block diagram of a barcode alignment circuit used in the invention.

Figure 13A is a block diagram of circuitry for driving scan elements for single line rotation and scanning; Figure 13B shows amplitude responses of a typical resonant scan element.

Figure 14 is a block diagram of circuitry for generating signals for producing a rotating Lissajous scan pattern.

Figure 15 depicts the amplitude and phase responses of resonant elements used for producing a rotating Lissajous scan pattern, in accordance with the invention.

Figure 16 is a perspective view of a rotating Lissajous scanner embodiment, implemented by four reflectors.

Figures 17A and 17B show two different reflector configurations for producing a rotating Lissajous scan pattern.

Figure 18 is a flow chart of trigger initiated, omni-directional scan pattern generation.

Figure 19 is a flow chart of automatic "aim and shoot" pattern generation, in accordance with the invention.

Figures 20A and 20B are side and front views of a miniature scanning assembly, in accordance with an embodiment of the invention.

Figures 21A and 21B are side and front views of a miniature scanner assembly, in accordance with another embodiment of the invention.

Figures 22A and 22B are views of a miniature scanner having an optical element mounted on two taut wires, in accordance with another embodiment of the invention.

Figure 23 is a simplified diagram showing two-dimensional scanning using an X-direction scanning element and additional Y-scanning motor.

Figure 24 is a symbolic drawing of a scanning assembly having a low-mass reflector oscillated by a permanent magnet-electromagnet mechanism.

Figure 25 is a diagram showing that the angle of oscillation of the low-mass reflector is considerably greater than that of the permanent magnet to which it is mechanically coupled.

Figures 26A and 26B are exploded views of two embodiments of palm-held scanner housings, together with a surface mount fixture, in accordance with the invention.

Figure 27 is a chart for explaining the operation of the scanner in portable and fixed modes for 1-D and 2-D barcode patterns.

Figure 28 is an exploded perspective view of a scanner module embodying the present invention;

Figure 29 is a partially assembled view of the scanner module of Figure 1;

Figure 30 is a fully assembled view of the scanner module of Figure 1; and

Figure 31 is a view from below of the scanner module of Figure 1.

As used in this specification, the terms "symbol" and "barcode" are intended to be broadly construed and to cover not only patterns composed of alternating bars and spaces of various widths, but also other one or two dimensional graphic patterns, as well as alphanumeric characters.

The invention provides a scanner system in which the scan pattern produced by a light beam is controlled to describe an omnidirectional scanning pattern, light reflected from a symbol is detected, and the scan pattern is thereafter controlled in response to the detected signals. The invention also provides a scanner system and method in which adjustment of the spatial coverage of the scan pattern of a scanning beam is automatically made at a responsively controlled rate to effect an appropriate type of scanning pattern depending upon the type of symbols to be read. The invention further provides a scanning system operation in which two different types of barcodes may be read, a standard linear barcode and a 2-D barcode. The invention provides a technique for determining the type of barcode, its angular orientation, and adjusts the spatial coverage or vertical sweep of the raster scanning beam to fully scan and read a 2-D barcode.

In accordance with a first aspect of the invention, the invention further produces scan patterns for reading indicia, optimized in dependence upon the operating mode of the scanner (portable or fixed) and other criteria. A portion of the barcode is

initially scanned by projecting a light beam on the target containing the barcode, and scanning the beam using a pattern that is relatively small and dense so as to be visible to the user for aiming. A portion of the barcode is partially decoded to determine the type, and possible size, of the barcode, whether it is a 1-D or 2-D barcode and its angular orientation. A rotating Lissajous pattern is preferred for this purpose as it has been determined to be most robust, although other patterns can be used. If the symbol is found to be a 1-D barcode, the scan pattern is increased in size (opened) to a maximum size, at a prescribed rate, in conformance with the portion of the symbol previously decoded, and the rotating Lissajous pattern decodes the entire symbol. If the symbol is determined to be a 2-D barcode, the rotating Lissajous pattern is converted to a raster pattern, and increased in size at a prescribed rate to decode the barcode. In a preferred embodiment, the raster pattern precesses so as to align with the 2-D symbol and therefore read 2-D barcodes of different angular orientations with respect to the horizontal scanning pattern.

Thus, referring to Figure 1A, a hand-held barcode scanner 30 is confined to be held in the palm of a user's hand and oriented in the direction of a barcode or other symbol 32 to be read. The scanner 30 is housed in a light-weight plastic housing 40 (Figure 1B) containing a semiconductor laser light source 42, photodetector 44, optics 46, 48 and 50 and signal processing/control circuitry 52. Alternatively, the housing may be gun-shaped and provided with handle to enable the user to easily manually aim and shoot the light beam toward a symbol which may be remote from the housing, and an indicator which may be an audio source inside the housing to inform the user that the housing is positioned in the correct working range for reading bar code symbols. Such a housing is shown in Figure 1 of U.S. Patent 5,168,149, incorporated herein by reference. The circuitry in housing 40 may be powered by connection to a power source, or by batteries 54 to allow the unit to operate in a portable, wireless mode.

As further depicted in Figures 1A and 1B, a suitable lens 38, or multiple lens system, will focus the scanned beam onto the barcode symbol at an appropriate reference frame. The light source 42 is positioned to introduce a light beam into the axis of the lens 38, and the beam passes through a partially silvered mirror 48 and other lenses or beam-shaping structure as needed. An oscillating mirror 50 is connected to a scanning motor 56 that is driven by the control circuitry 52 in response to manual operation of a trigger 58 on the outside of the housing 40 (Figure 1A). Signals to and from the control and signal processing circuitry 52 are carried by exit port 34a and line 34 to external equipment.

The scanner 30 may be adapted to scan different types of articles or for different applications by interchanging the scanning head with another through use of electrical connectors. Furthermore, the scanning module may be implemented within a self-contained data acquisition system including one or more such components as keyboard, display, printer, data storage, application software and data bases (see, for example, U.S. Patent 4,409,470), and may also include a radio or other type of communications interface for communication with a local area network, telephone exchange network or radio broadcast system.

Referring to Figure 26A, the palm scanner module 30, now shown in more detail, incorporates a rubber grip 110 around the crown of the module slightly above a pair of indentations 112 for seating the module in a mounting bracket 114, enabling the module to pivot about a horizontal axis. The bracket 114 includes a pair of upstanding supports 116 having spindles 118 for rotatably supporting the module. The bracket 114 in turn is mounted on a base 120 that is turreted to a mounting plate 122 and hence is able to rotate about a vertical axis. The scanner module 30 can be easily removed from the bracket by lifting with a force sufficient to enable the spindles 118 to slip from the indentations 112.

The outgoing beam 36 is generated in the scanner 30 by a laser diode or the like, and directed to impinge upon the barcode symbol 32 that ordinarily is positioned a few inches from the front of the scanner. However, other applications may require scanning a target that is at a considerable distance, e.g., 60 feet from the scanner. The outgoing beam 36 is scanned using various patterns to be described later, one being a linear raster as shown in Figures 2A and 2B. The user positions the hand-held unit so that the scan pattern traverses the symbol to be read. Light reflected from the symbol is received by the unit 30 and detected by a photodetector 44 within the housing. Light beam 36, in both directions, passes through a transparent or translucent window 38 that preferably is approximately square in shape to accommodate 2-D as well as 1-D pattern scanning.

Referring to Figure 2A in more detail, a raster scanning pattern, known in the art, is traversing a 1-D barcode. Such a scan pattern may be generated by vertical (or Y-direction) displacement of a linear scan line driven in the X-direction, such as described in U.S. Patent 4,387,297. Although numerous scan lines traverse the barcode, only one line of scan is necessary for proper decoding since the additional scan lines are redundant and only reread the same data on a different vertical position

of the barcode symbol. In Figure 2B, the raster traverses a 2-D barcode, and is opened vertically to encompass the barcode entirely. Although the 2-D pattern contains many rows of optical elements, it is necessary only that each row be traversed once, as shown, for decoding.

For long range scanning, first aiming and then scanning the barcode to read the code is natural. These operations are termed the "aim mode" and "decode mode" hereinafter. Two trigger pull positions are normally provided, or the trigger is pulled twice to produce these respective modes of operation. In accordance with one aspect of the invention, and referring to Figures 3A and 3B, upon a first pull of the trigger 58, a bright spot for aiming is used to establish a small visible pattern on the target surface. This technique is similar to that disclosed in U.S. Patent No. 5,117,098 of Swartz and assigned to the assignee of this invention. This visible pattern may be produced by a small scan line, but preferably is presented in the form of a bright spot. This "spot" can be developed, and is presented in most visible form, by an oscillating circle, or spiral, pattern shown in Figure 5C. Other patterns found suitable for aiming are rosette (Figures 5A and 5B), stationary Lissajous (Figure 5D), rotating line (Figure 5E) and rotating Lissajous (Figure 6).

For example, the line scan pattern of Figure 5E is produced by generating a beam of a relatively short line scan pattern, and rotating the pattern quickly about its center once or after every few scans. Alternatively, the scan line may be randomly positioned at pre-determined angles, once or after every few scans, and the angle of rotation about its center of rotation may be controlled in response to signals read produced by light reflected from the symbol. Assuming that the spot is located in nearly the center of the barcode, the orientation of the barcode may be estimated using a peak detector, to be described later, if the barcode is a 1-D barcode or the orientation may be estimated from the returned digital bar pattern, or DBP, as the scan line is positioned at different angles.

Upon the second trigger pull (or further pull of the trigger in the same stroke if the trigger is multi-purpose), or automatically, in the decode mode of operation, the scan pattern opens in the exact orientation of the barcode as determined by the peak detector, as shown in Figure 3B, so that the entire barcode will be decoded. The ultimate size of the rotating scan line pattern, and the rate at which the pattern opens, is controlled dependent upon barcode attributes, such as type, aspect ratio and size, decoded during the aim mode. Optionally, the barcode may be completely decoded during the aim mode, and if so, a consistency check may be performed during the decoding mode.

The following example assumes an aim pattern in the form of a single scan line, Figure 5E, a pattern particularly useful for discerning the orientation of a barcode prior to decoding. In order to rotate a single scan line, or position it at any given angle, an element having two degrees of freedom with equal resonant frequencies on both axes is necessary. The horizontal and vertical oscillations are given by

$$\hat{X}(t) = \sin(wt)\cos(\theta)$$
$$\hat{Y}(t) = \sin(wt)\sin(\theta)$$

where $\theta$ is the angle of rotation with respect to the x-axis. This angle will normally be produced in the form of a digital quantity presented to the rotation system via a microprocessor system. The resonant frequency w should be chosen high enough so that a possible loss in aggressiveness during the angle estimation/aiming period is not apparent.

In order to cover all possible orientations of the barcode, the scan lines must be capable of rotating through 180 degrees, and preferably the entire symbol will be covered such that at least two scan lines traverse each row of bar patterns during reading. However, the resolution of rotation depends on the aspect ratio and size of the barcode.

If it is necessary to rotate the scan line once every s scans, at a resolution of r degrees, for a duration of d seconds in order to cover a total of 180 degrees, then

$$w = \frac{180\pi s}{rd}$$

is selected.

For example, if a complete 180 degree rotation should be accomplished within 0.1 second, at 10 degree resolution for every scan, then $w/2\pi$ = 90Hz will suffice.

Referring to Figures 10-12, means for detecting when the scan line of Figure 5E is aligned to a barcode are shown. In Figures 10A and 10B, the barcodes and scan line are in alignment and out of alignment, respectively. The DBP (digital bar pattern) stream corresponding to the scanned barcode is analyzed to find the scan angle at which the energy content of the DBP stream is maximum because the scan line has intersected the most barcode elements. In Figure 10A, the DBP pattern scanned by line 75a has more elements than that of Figure 10B where the barcode has been scanned by a skewed scan line 75b. As the scan line is rotated, the number of elements produced in the DBP stream is estimated by filtering and com-

paring with the stream produced by other scan line angles. Hence, referring to Figure 11, the DBP stream is read and supplied as an analog signal (a) derived from the DBP stream to a high pass filter 70 which produces waveform (b). A peak level detector 72 tracks the peak value or envelope of the filtered replication of the DBP stream (see waveform (c)), and the peak value is compared to a prescribed threshold (e) by comparator 74. The points at which the envelope and threshold intersect each other develop an output signal (e) having a duration that corresponds to the number of DBP elements spanned by the scan line. The duration of the output signal is measured by timer 76, to indicate the number of elements of the DBP stream, and the scan line producing a DBP stream of greatest duration is identified as having the best alignment to the barcode.

The orientation of the scan line alternatively may be determined more precisely than what is capable using the circuit of Figure 12 by implementing an algorithm wherein the DBP stream is read and scanned for regions bound by a known scan direction synchronizing signal (called "SOS") having the most elements. For example, the orientations between five and ten degrees may have one hundred elements, while all others have fewer. If the scan line is shorter than the barcode, then this region between five and ten degrees, for example, will indicate the general barcode orientation. A more exact orientation can be found by rotating the scan line in a direction that minimizes the total sum of these element widths. Once the exact orientation is found, the scan line length may be increased until a decode occurs. Hence, this approach represents a global search for general barcode orientation, and then a fine tuning step.

The circuit of Figure 12 is more immune than the algorithmic approach, as the threshold of comparator 74 may be set to ignore spurious elements due to noise.

Although the short single line pattern is the most visible, it is disadvantageous for aiming because it suggests orientation and may be psychologically distracting. Larger spots, those shown in Figure 5A-D, can be simulated without changing the aperture by creating the spiral pattern shown in Figure 5A, implemented by modulating the size of a circle pattern. As mentioned previously, a spiral is the most visible, non-orientation, suggestive and easily implemented. All of the aim patterns of Figure 5A-D can be created by the circuit shown symbolically in Figure 8, which implements the following equations:

$$x(t) = \sin(w_2 t)A(t) \quad (1)$$

$$y(t) = \cos(w_1 t)A(t) \quad (2)$$

The function A(t) can be arbitrarily picked. For example, let $A(t) = \sin(w_3 t)$. The rosette pattern of Figure 5A is created with $w_1 = w_2$, and $w_3 = 4w_2$; the rosette pattern of Figure 5B is created with $w_1 = w_2$, and $w_3 = 2w_2$; the spiral pattern of Figure 5C is created with $w_1 = w_2$, and $A(t) = |\sin(w_2/50)|$; and the stationary Lissajous pattern of Figure 5D is created with $w_1 = w_2/1.1$, and $A(t) = 1$. The rotating line pattern, Figure 5E, is created by having the modulating function $A(t) = \sin(w_{scan}t)$ and $w_1 t = w_2 t = \theta$ where $\theta$ is the angle of the scan line, and $w/2\pi$ is the scanning frequency.

Another pattern which may be used for aiming, and which will be described in more detail later, is the rotating Lissajous pattern shown in Figure 6. The rotating Lissajous pattern is somewhat inferior for aiming because its visibility is less pronounced than other patterns, but is particularly advantageous insofar as its ability to decode during aiming is the most robust of all the patterns considered.

Another pattern for aiming found particularly effective is a bright rosette pattern of diameter less than the diameter of rosette to be used for decoding.

Once satisfied with aiming, the scanner begins to deflect the light beam with a scan pattern appropriate for decoding the barcode. The scan pattern for decode may be the same as for aim, or may be a different pattern or may be the same or different pattern with center of rotation that shifts upon transition between the two modes or during decoding. In a preferred embodiment, the decode scan pattern which is generated depends upon whether the barcode is found to be a 1-D barcode (when the preferred decode pattern is omni-directional) or a 2-D barcode (when the preferred decode pattern is raster). Pattern switching may be responsive to a second trigger pull, or may occur automatically.

For example, referring to Figure 4A, it is assumed that a rotating Lissajous aiming pattern is directed toward a target having a 2-D barcode, as shown. The barcode is partially decoded to determine barcode type and orientation. The first row of the barcode may be decoded to determine whether the barcode is a 1-D or 2-D barcode. Alternatively, an algorithm may be used that is capable of determining whether the portion read is a portion of a 1-D or 2-D barcode on the basis of code words detected and decoded.

Upon determining, in this example, that the barcode is a 2-D barcode, the scan pattern is changed to a raster pattern, as shown in Figure 4B, necessary for scanning such barcodes. Based upon data read from the barcode during the aim mode, the width of the scanning pattern is opened until it at least spans the width of the barcode, and the height is incremented until the entire barcode is

decoded. As the scanning pattern is increased in height, the barcode rows encompassed by the scanning pattern will be read, decoded and interpreted to determine whether an entire 2-D barcode symbol has been scanned, as described in U.S. Patent 5,235,167. Each row the bar code will preferably be traversed by at least two scan lines, although only one traversal is necessary. Once the symbol is read, feedback to the user in the form of, for example, an audio tone, may be presented by the control/processing circuitry within the bar code reader.

Preferably, the specific pattern produced by the scanner, in accordance with an important aspect of the invention, is a pattern that is optimized for a particular classification of indicia and depending on whether the scanner is operating in a portable mode or is mounted in its fixture. A scan pattern is deemed to be optimized if it reads and decodes a prescribed pattern in a minimum amount of time, and within reasonable economic constraints.

If the scanner is operated in the fixed mode, with the palm held module 30 is mounted in bracket 114 and the module 30 directed to a region across which items bearing indicia, such as a barcode, to be read are passed, the rotational orientation of the scan pattern with respect to barcode is indeterminate. On the other hand, if the scanner is operated in the aim and shoot mode, with the module 30 separated from the bracket, the scanning pattern may be manually aligned with the barcode. The specific pattern produced should be optimized for decoding barcodes of the particular classification of barcode being read.

Hence, in accordance with an aspect of the invention, and referring to Figure 27, a suitable scan pattern is produced for determining classification of the symbol to be read, e.g., whether the symbol is a 1-D or 2-D barcode. In the example shown, a rotating Lissajous scanning pattern is selected for its omnidirectionality and robust decoding ability. At the same time, it is determined whether the scanner is in the portable mode or fixed mode of operation (the order of sequence of the first two steps is arbitrary). This may be carried out by detecting the presence of the module 30 in bracket 114 by means of, e.g., a mechanical or magnetic proximity switch in the base of the fixture (not shown in Figures 26A, 26B; however, see U.S. application serial number 08/028,107, filed March 8, 1993, incorporated herein by reference), or by a manual switch located on module 30 or elsewhere.

Assume first that the scanner is in the fixed mode of operation and arranged to read a barcode symbol. The symbol is preliminarily read using the rotating Lissajous scan pattern to detect the start and stop codes of the barcode, so as to determine whether it is a 1-D or 2-D barcode. If the symbol being scanned is determined to be a 1-D barcode, the scanning pattern will remain defaulted in the form of a rotating Lissajous pattern, as shown in Figure 27, a pattern that has been determined in accordance with the invention to be optimized for 1-D barcodes. If the symbol is determined to be a 2-D barcode, on the other hand, the scanning pattern is changed to a self-aligning raster, as also shown in Figure 27. (A self-aligning raster is a raster that rotates or precesses so as to traverse a 2-D barcode and read it independently of the rotational orientation of the barcode. A specific embodiment of self-aligning raster is a precessing raster described in more detail later with reference to Figure 7.)

Still referring to Figure 27, when the scanner is determined to be operating in the portable mode, and the symbol as read during Lissajous scanning is determined to be a 2-D barcode, the scanner produces a raster type scanning pattern. This raster is preferably stationary, but may be enhanced to precess or rotate so as to read barcode symbols of diverse rotational orientations. On the other hand, if the symbol is determined to be a 1-D barcode symbol, scanning is continued in the form of a pattern optimized to read such barcodes, such as a single or rotating scan line, or rotating Lissajous.

The particular scanning patterns produced for decoding 1-D or 2-D barcodes when the scanner is operated in portable and fixed modes can be varied for specific applications and modules of particular optical characteristics. What is important is that the scanner is adaptive, controlled manually but preferably automatically, to produce decoding scan patterns that are optimized, that is, as robust as practical with respect to the operating mode selected and the classification of indicia being read.

Preferably, the scan pattern is also optimized in dependency on whether scanning is carried out by a presentation type (under a scan lamp) or a pass through (supermarket) type reader. In the presentation type reader, an article carrying a barcode or other symbol to be read is brought to the reader or the reader is brought to the article. Since reading is carried out in very close proximity to the barcode, there is no need for aiming. In the pass through reader, the article bearing a barcode is swiped past a scanning pattern produced by a fixed source of light beams. These two modalities present different decoding requirements to barcode readers (in the pass through mode of reading, the article swipes through the scan region relatively quickly, whereas in the presentation mode, the barcode is relatively stationary when read). Hence, if reading is carried out in the pass through mode,

and the barcode is not very truncated (that is, the barcode is thin), a scanning pattern producing lines that are more sparsely spaced but more often repeated is preferred because it is more likely to traverse the barcode. That is, the faster the swipe, the thicker the barcode should be and hence a scanning pattern, such as a rotating Lissajous pattern, optimized for a relatively thick barcode pattern is preferred.

Assuming now that the rotating Lissajous pattern is generated (Figure 4A) for aiming, in aim and shoot scanning. Another important aspect of the present invention is that the rate of increase of the size of the raster in moving from Figure 4B to Figure 4C is responsively controlled depending upon the size and nature of the barcode. The rate at which the scan pattern opens may be controlled to be faster for larger barcodes. The size of each increment may be dependent upon the working range of the scanner. For example, very long range scanners, e.g., up to about 60 feet, may require smaller increments so that the patterns do not grown too fast at the end of the working range.

The preferred Lissajous pattern for decoding, shown in Figure 6, is preferably of frequency ratio x/y ranging from 1.1 and 1.3 and rotated at a rate of between 1 to 4 degrees per scan. These numbers are found optimal for scanning highly truncated 1-D barcodes. In this respect, the rotating Lissajous pattern, with its sequence of scanning patterns that are successively rationally offset, has been found more robust for decoding than a stationary Lissajous pattern. The optimal stationary Lissajous pattern is at a frequency ratio 0.7. However, the optimized rotating Lissajous pattern produces a 17% improvement in decoding efficiency over the stationary Lissajous pattern. When the rotating Lissajous pattern is converted to a raster for scanning 2-D barcodes in omni-direction, the frequency ratio is made higher by increasing the slower scan frequency y.

Single line rotation and scanning is produced, in accordance with the invention, by driving two mirrors (not shown) using the circuit 80 of Figure 13A which corresponds to, but is more detailed than, Figure 8. The two mirrors are mounted on resonant scan elements having relative resonant frequencies at wa and wb, respectively, shown in Figure 13B. To implement oscillation of the two mirrors for scanning in X- and Y-directions, satisfying the relationships given in equations (1) and (2), the circuit 80 implements a processor 82 that estimates the orientation of the barcode based on element counts in the DBP stream and/or start and stop character detection. A scan line will be opened upon the second trigger pull at an angle based on the last detected barcode orientation. The processor 82 addresses EEPROM cosine and sine tables 84 and 86 which generate digital data corresponding to amplitudes of the cosine and sine of the prescribed angles. These digital signals are multiplied by sin(wt), and the product converted to a corresponding analog signal in multiplying digital-to-analog converters (DAC) 88 and 90.

Amplitude control shown herein assumes that the Y-element will be driven somewhat harder than the X-element so as to compensate for any slightly leading resonant peak, as depicted in the amplitude response curves of Figure 13B. Similar compensation may have to be carried out to equalize the phase responses. Here, it is assumed that the X-element is leading in phase. The phase adjustment is performed by phase adjustment circuits 92 and 94. The outputs of the phase adjustments 92, 94 are supplied to the X- and Y-inputs of resonant scan elements 96.

Resonant scan elements are known in the art. Such elements typically are provided with a flexural strip of Mylar or other material cantilever mounted to a base and supporting a miniature permanent magnet positioned within a coil. The coil is secured to a base, and a scan mirror is attached to the free end of the cantilever mounted flexural strip. By changing the dimensions or flexural characteristics of the cantilever mounted strip, the mass of the strip, the permanent magnet and mirror, or the distribution of mass on the flexural strip, different resonant frequencies can be established. See, for example, copending application Serial No. 07/884,738, filed May 15, 1992 and incorporated herein by reference.

The resonant scan element can also be presented as a single element having different resonant frequencies in mutually orthogonal directions, and utilizing a single mirror to perform single line rotation and scanning. The circuit 80 of Figure 13A can be implemented to apply drive signals for X- and Y-scanning to the two inputs of the dual-resonance scanning element, as disclosed in the copending application.

To produce 2-D scanning patterns for symbologies such as PDF 417, described in U.S. Patent Application Serial No. 07/461,881, filed January 5, 1990, the resonant scan element must be capable of being simultaneously driven by at least two frequency components. Raster pattern rotation is achieved by driving a 2-D scanner such that the horizontal element is driven with the signal X(t) and the vertical element is driven with the signal Y(t), where

$$\overline{X}(t) = \sin(w_1 t)\cos(\theta) - \sin(w_2 t)\sin(\theta) \qquad (3)$$

$$\overline{Y}(t) = \sin(w_1 t)\sin(\theta) - \sin(w_2 t)\cos(\theta) \qquad (4)$$

and $\theta$ is the angle of rotation in digital form.

The above equations describe a rotating Lissajous pattern, and in fact, any Lissajous pattern may be rotated if the two sine functions are replaced by their Lissajous equivalent. If the resonant scan element has the desired equal amplitude and phase responsive at the two sinusoidal components of each drive axis, as illustrated in Figure 16 depicting the frequency response shapes of resonant scan elements for 2-D scanning, then no added compensation for phase and amplitude is required.

A circuit 98 for developing drive signals for Lissajous pattern rotation, shown in Figure 14 and described by equations (3) and (4), comprises a processor 100 addressing sine and cosine EEPROM tables 102 and 104 that produce the sine and cosine values of the angle, in digital form, generated by the processor. These sine and cosine digital values are supplied to multiplying DAC units 106 to produce the analog sine and cosine functions of the above equations.

The four drive signals produced by circuit 98 of Figure 14 may be applied to four resonant elements supporting four reflectors, each oscillating at a single resonant frequency, as shown in Figure 17 and identified by numeral 110.

A first pair 112, 114 of the mirrors 110 is optically combined as X-axis elements having two resonant frequencies. The second pair is arranged as a Y-axis element having two resonant frequencies that match those of the first pair. The mirrors may be oriented in either of the configurations of Figures 15A and 15B.

Alternatively, each mirror pair may be combined on a single resonant element wherein a distinct resonant peak is available for each axis. The element hence can be driven at its resonance frequency by the higher frequency w2 and off resonance by the lower frequency w1, but with a larger amplitude and any necessary phase compensation. Resonance elements of dual resonant frequency response may be arranged orthogonally to produce the rotatable raster patterns in this case.

Figures 9A-9D are raster patterns scanning 2-D and 1-D barcodes, respectively, in perfect alignment. However, in practice since the orientation of the scan pattern will not be in perfect alignment with the barcode; scanning typically will be somewhat skewed as shown in Figures 9B and 9E. Furthermore, since 2-D scanning mechanisms tend to be slightly non-linear and will ordinarily produce a somewhat arcuate, or drooped, scan pattern as shown in Figures 9C and 9F, decoding of the barcode is somewhat difficult to achieve when a complete row of barcode is not entirely scanned.

To compensate for rotational misalignment between the scan pattern and barcode, or droop in the scan pattern, another aspect of the invention precesses the raster so as to traverse barcode elements that are angularly displaced or are not oriented along a straight line. Referring to Figure 7, the angle of sweep of each line by the raster scanner is staggered or precessed slightly, so that the light beam sweeps across the barcodes in a zig-zag pattern. Precession whereby subsequent scanning patterns are rotationally offset from a previous pattern, occurs when the ratio of the X component to the Y component of the scanning pattern is not an integer. In the preferred embodiment, the scan ratio is 1.75:1. For example, if the X component frequency is 120 scans per second, then the Y component frequency is 68.5 scans per second (120 divided by 1.75). The scanner can be designed such that the scan ratio is always 1.75:1, although precession alternatively can be achieved by activating the Y frequency scan by a computer driver. Preferably, each row of the bar code will be traversed by two lines of scan, although only a single scan line per row is necessary.

The resultant zig-zag pattern causes the light beam to sweep the barcode symbols in a plurality of different angles, so that angularly offset lines of barcode up to about thirty degrees of offset can be read by the raster during precession. Similarly, even if the beam emitted by the scanner contains a degree of droop, the precessing raster will scan every barcode line during successive frames.

The processors 82 of Figure 13A and 100 of Figure 14 are programmed to control the scanner of this invention in the aim and decode modes, either by manual (trigger) operation or automatically as described previously. Programming of the processors will now be described with reference to the flow charts of Figures 18 and 19. Figure 18 represents scanner operation for either 1-D or 2-D barcodes, wherein the trigger must be operated once for aim and a second time for decode. In Figure 19, describing a 1-D barcode scanning example, the transition between aim and decode modes of operation is automatic. In some cases, the requirement to operate the trigger twice for aim and decode is preferable, to prevent a symbol from being decoded prematurely or decoding a neighboring barcode.

Referring to Figure 18, the scanner awaits a first operation of the manual trigger, and when the trigger has been first depressed, as detected in step 100, the scanner generates the aim mode pattern which, as aforementioned, preferably is an omnidirectional pattern (an omnidirectional pattern is one wherein the scan angle the beam traverses over time is not limited) and may be any suitable scan pattern that is radially symmetric, e.g., not a simple raster pattern, including those shown in Figures 5A-E or Figure 6; the oscillating circle or spiral pattern (Figure 5C) being best from a stand-

point of visibility and the rotating Lissajous pattern being best from the standpoint of preliminary decoding of the barcode (step 102).

The scanner now waits for another trigger operation, and when the trigger has been manually operated for the second time, as determined in step 104, an omni-pattern for decoding is generated by the scanner (step 106). In the example of Figures 4A and 4B, as described previously, the aim pattern in the form of a rotating Lissajous for aiming transitions converts to a raster for decoding, and as shown in Figure 4C the aiming pattern is incremented in size (step 108) until the maximum size of the pattern is exceeded (step 110) when the scan pattern is reset in step 112 to increment again.

If, however, the barcode has been fully decoded, determined in step 114, before the maximum size of the scan pattern is exceeded, the routine is completed.

The size of each pattern increment, and the rate at which the increments are generated, are preferably controlled in response to data read from the symbol during the aim mode to achieve an optimal rate of Y-direction expansion depending on the number of rows in and height of a label. If the 2-D code is not successfully decoded at step 114, then decoding is continued until either a successful decode has occurred or until a predetermined amount of time, typically on the order of three seconds, has elapsed.

In accordance with Figure 19, transition from the aim mode to the decode mode is made automatically, and for this example, the procedure is particularized for scanning a 1-D barcode, although the procedure could be generalized to encompass 2-D barcodes as well.

In response to manual operation of the trigger, in step 120, a rotating line pattern (step 122), corresponding to what is shown in Figure 5E, is produced. Alignment of the rotating line pattern and barcode is monitored in step 124, and may optionally be fine tuned in accordance with step 126. Alignment may be performed in accordance with the procedure of Figure 11 and circuit of Figure 12.

A second manual operation of the trigger per step 128 is optional. Even if the trigger is not operated at this time, when the decoder has determined the optimum angle at which to emit a decode scan pattern, the pattern is produced (step 130). The line size is incremented (step 132) until it exceeds the length of the barcode (step 134). If the maximum size is exceeded, the size of the scan line is reduced to the minimum size for aiming (step 136) and the process repeats. During the time the length of the scan line is incremented, the barcode is being decoded, in step 138, and when decoding is completed, the routine is terminated.

In either the manual or automatic operations, the light beam directed toward the symbol to be read is transitioned between first and second scan paths in the aim and decode modes. In addition to transition between the scan paths described above, the first and second scan paths may differ from each other by rotation about an axis of rotation, by increase in scan path envelope diameter, by both rotation and envelope diameter increase and by displacement of the center of rotation of the first scan pattern.

The user can, therefore, simply aim an apparent spot on the barcode, without regard for the barcode's orientation, and then decode it upon the second trigger pull. It is also possible to provide automatic scan line opening without a second trigger pull. However, there is a danger that the scanner may unintentionally scan and decode the wrong barcode.

In accordance with another aspect of the invention, a first embodiment of a scanning element that may be used to produce the prescribed scan patterns is shown in Figures 21A and 21B. In Figure 21A, a scan module 110 supports and oscillates an objective lens 112 that is mounted on a circuit board 114 that also carries four electric coils 116 equally spaced along the four quadrants of the circuit board. A support member 118 has a central opening 120 for receiving and retaining a light emitting diode 122 that preferably is a laser diode. At a side of the support 118, opposite the diode 122, is a permanent magnet 124 that interacts with an electromagnetic field produced by the coils 116 when an electric current is applied.

The circuit board 114 and support 118 are interconnected by four semi-rigid wires 126 that also carry electric current from a driver circuit to the four coils. By changing the connections between the coils, 1-D or 2-D scan patterns may be selectively achieved.

Wires 126 preferably are tin-soldered to the circuit board 114 and support 118. The material of the wires preferably is a phosphor-bronze alloy, although any other material that conducts electricity and provides semi-rigid support of the circuit board 114 and lens 112 with respect to support 118 may be used.

Magnet 124 is in the form of a ring, and in one embodiment may be magnetized axially. The central hole of magnet 124 serves as an aperture stop for the laser beam.

Alternatively, the permanent magnet 124 may be multiply poled around its circumference. For example, the poling of the permanent magnet may be such that there are four poles, with South poles being oriented at 0° and 180° and North poles at 90° and 270° along the circumference. By suitably energizing two of the four coils 116, the lens

and coil assembly will rotate slightly, and hence the semi-rigid wires will begin to form a helix, reducing the distance between the lens 112 and laser beam source 122 to focus the beam. The other two coils are energized to oscillate the lens assembly to produce appropriate scanning.

Another embodiment of scanner, shown in Figures 20A and 20B, comprises a casing 130, of bakelite or other suitable material, and of cylindrical configuration. Within the casing 130 is seated a soft iron disk 132 having apertures to accommodate a number of terminals 134 for supplying electric current to an electromagnetic coil 136 positioned on the disk 132. Surrounding the coil 136 within casing 130 is a ring magnet 138 for producing a magnetic field that interacts with the electromagnetic field produced by coil 136. A soft iron core 140 is positioned in the central aperture of the coil 136, and a thin diaphragm 140 of flexible material is seated on the end of magnet 138, as shown, spanning the coil 136 and its core 140. On the outer surface of the diaphragm 140, near the end of core 140 is a thin metal plate 144 of low mass.

Pivotably mounted to the end of casing 130 at 146 is a piece of film 148, preferably made of Mylar. Upon the outer surface of the membrane, at a position in longitudinal alignment with core 140, is a reflector 150. The reflector 150, together with its supporting membrane 148, is maintained separated from the diaphragm plate 144 by another piece of film 152, again preferably formed of Mylar.

Except for Mylar films 148, 152, and reflector 150, the device shown in Figures 20A and 20B is of a type conventionally used as an audio beeper, wherein an audio signal applied to leads 134 produce oscillation of the membrane 142 and its attached plate 144. In the present invention, mechanical coupling between reflector 150 and membrane 142, by virtue of Mylar film 152, causes the mirror 150 to oscillate correspondingly, and, if coil 136 is suitably energized, scan.

Another embodiment of a scanning mechanism, in accordance with the invention, is shown in Figures 22A and 22B as 148, wherein 1-D scanning is carried out by a scanning element in the form of a bracket, or tensioner, 150 that is of integral construction, generally C-shaped in configuration and resilient. Spanning the ends of the bracket 150 is a closely spaced, parallel pair of wires 152 maintained taut by the spread of the bracket. Attached to the taut wires 152, and essentially located thereon, are a reflector 154 and permanent magnet 158, secured to the wires by a clamp 156.

Within the bracket 150, behind the magnet 158, is an electromagnetic coil 160 which, when energized, produces an electromagnetic field that interacts with the field of the permanent magnet to oscillate reflector 154 in one direction, for example, the X-direction.

An important advantage of the structure of the scanner mechanism shown in Figures 22A and 22B is that with mirror 152 floating within the ends of bracket 150, attached to the pair of taut wires 152, strain is uniformly distributed along the wires. This represents an improvement over a scanner implementing a taut band to support an optical element, such as is described in U.S. Patent 5,168,149, where strain tends to concentrate at the ends of the band.

To produce 2-D scanning using the mechanism of Figure 22, a separate reflector 162, for deflecting the light beam in the Y-direction, is oscillated by a Y-motor 164. The configuration, shown in Figure 23, with the taut-wire X-scanner 148 of Figure 22, together with a laser beam source 166 and Y-scanner 162, 164 in the configuration shown, produces a compact scanner assembly.

Another embodiment of scanner, shown in Figure 24, comprises an electromagnetic coil 172 having a central opening into which partially extends and electromagnetic coil 174. The coil 172 is rigidly secured to a support member (not shown), and the magnet 174 is resiliently coupled to the same support by means of an arm 176.

A U-shaped spring 178 is attached to the magnet 174 at one end, and the opposite end of the spring supports an optical element, preferably a reflector 180. Electrical leads (not shown) carry an energizing current or drive signal to the coil of electromagnet 174. The reflector 180 will oscillate in response to such electromagnet coil signal so as to scan in one or two dimensions, selectively. The spring 178 may be made of any suitable flexible materials, such as a leaf spring, a flexible metal coil or a flat bar having sufficient flexibility properties, and may be of a material such as a beryllium-copper alloy.

The reflector 180 is positioned between a laser beam source and lens assembly 182 and a target (not shown in Figure 24). Between the reflector 180 and source 182 is a collector 184 having an opening through which a light beam emitted by the laser source 182 may pass to the reflector 180. The collector is oriented so as to direct incoming light, reflected by reflector 180 and then collector 184, to a photodetector 186.

An important aspect of the embodiment of Figure 24 is that the mass of reflector 180 is considerably less than the mass of permanent magnet 174. The mass of the mirror is selected to be less than about one-fifth the mass of the magnet, and the angle of vibration of the mirror as shown in Figure 25, a diagram derived by computer simulation, is about seven times that of the permanent magnet.

The reflector 180 is capable of 2-D scanning. As described in copending application Serial No. 07/943,232, filed on September 10, 1992, the U-shaped spring 178, which may be formed of a plastic material, such as Mylar or Kapton, the arms of the U-shaped spring 178 and the planar spring 176 may be arranged to vibrate in planes which are orthogonal to each other. Oscillatory forces applied to permanent magnet 174 by the electromagnetic 172 can initiate desired vibrations in both of the springs 178 and 176 by carefully selecting drive signals applied to various terminals of the coil, as discussed in the copending application. Because of the different frequency vibration characteristics of the two springs 178 and 176, each spring will oscillate only at its natural vibration frequency. Hence, when the electromagnetic 172 is driven by a super position signal of high and low frequency components, the U-shaped spring will vibrate at a frequency in the high range of frequencies, and the planar spring 176 will vibrate at a frequency in the low range of frequencies.

An additional important aspect of the embodiment of Figure 24 is that the laser beam emitted by source 182 impinges the reflector 180 at an angle that is orthogonal to the axis of rotation of the reflector. Hence, the system avoids droop in the 2-D scan pattern that tends to arise when the angle of incidence of the laser beam is non-orthogonal to the reflective surface.

Another important aspect of Figure 24 is in the folded or "retro" configuration shown, with the laser beam source 182 off axis from that of the beam directed from the reflector 180 to the target. The detector field of view follows the laser path to the target by way of collector 184. The folded configuration shown is made possible by opening 181 in the collector. The retro configuration enables the scanning mechanism to be considerably more compact than heretofore possible.

Optionally, the bracket 116 may be mounted on an extension tube 124, shown in Figure 26B, so as to offset the module 30 from a support surface and enable tall items to be scanned.

Hence, as described herein, the invention produces a rotating Lissajous scan pattern or other pattern that is easily seen by the user during aiming on a barcode, and then under manual control or automatically converts to a decode scan that is robust and opens at a rate, and to a size, that depends upon the barcode itself. If the barcode is a 1-D code, the decode pattern may be a precessing raster that is able to scan rows that are rotationally misaligned with the scan lines. Scanning is implemented by novel miniature 1-D and 2-D scanning assemblies, as described herein.

Another form of scanner that can produce the required two-dimensional scanning patterns is of a type implementing a scan element supported by a holder structure mounted on a mylar motor to produce oscillatory movements, the arrangement being mounted on a printed circuit board within a housing that can be manually held. The scanning motor and arrangement may be made of components formed essentially of molded plastic material, and utilizing of a mylar leaf spring to limit scan. See, for example, application serial number 07/812,923, filed December 24, 1991, assigned to the assignee of this invention and incorporated herein by reference.

Reference should next be made to Figures 28 to 31, which illustrate the preferred scanner module within which the scanning arrangement of Figures 24 and 25 may be incorporated. For ease of reference, parts of the module already described with reference to Figures 24 and 25 will be given the same reference numerals.

As may best be seen in the exploded view of Figure 28, the preferred scanner module consists of two separate sections: a chassis element 10 and a scan element 12. In Figure 28, these two sections are shown in exploded form, prior to their securement together during the assembly process.

As is best seen in Figures 30 and 31, the chassis element 10 comprises a chassis 14 which carries the coil 172. The coil 172 is secured to a rear wall 16 of the chassis. At respective ends of the rear wall there are first and second forwardly-extending side supports 18, 20. The forward end of the side support 18 is provided with a vertical slot 22 (Figure 30) into which is placed (Figure 4) the collecting mirror 184 previously referred to. The forward part of the other side support 20 is provided with a larger vertical slot or cavity 24 (Figure 30) into which the photodiode assembly 186 (Figure 31) fits.

The features of the scan element 12 (which is during assembly secured to the chassis element 10) is best seen from a comparison of Figures 28, 29 and 31. The scan element comprises a beryllium-copper bracket generally shown at 26 having a vertical mounting portion 28 in a plane perpendicular to the axis of the coil 172. The upper part of the mounting portion is formed with two rearwardly-pointing prongs 30, 32 (not visible in Figure 31). Secured to the mounting portion 28 is the spring 178, previously mentioned with reference to Figure 24, which carries the mirror 180. On either side of the prongs 30, 32, the upper edge of the mounting portion 28 is bent backwardly to form first and second hanging brackets (34, 36, best seen in Figures 28 and 29). Screwed to these hanging brackets are respective first and second sheets of Mylar film 38, only one of which is visible in Figures 28 to 30. At the top of the Mylar sheets are secured respective hangers 40, 42.

The scanner module is assembled by bringing the scan element 12 up to the chassis element 10 and using screws 44, 46 to attach the hangers 40, 42 to respective bosses 48, 50 on the chassis side supports 18, 20. The relative positioning of the chassis element and the scan element, just prior to their securement together by the screws 44, 46 is shown most clearly in Figure 29.

It will be appreciated that once the scanner module has been assembled, as described, the entire weight of the scan element, including the mirror 180, is supported by the hangers 40, 42 and the sheets of Mylar film 36, 38. The entire scan element is accordingly free to rock back and forth about a horizontal axis perpendicular to the axis of the coil 172 as the Mylar film flexes.

The operation of the device will now be described, with reference to Figure 31. A laser beam, emanating from the laser beam source and lens assembly 182, passes through the hole 181 in the collector 184, and impinges upon the mirror 180 from which it is reflected via a window 52 to a bar code symbol to be read (not shown). Energisation of the coil 172 causes oscillation of the mirror 180 in two directions: a first direction due to flexing of the spring 178 and a second direction due to flexing of the Mylar film 38. By appropriate control of the coil, a variety of scanning patterns can be produced, for example a raster pattern or other types of two-dimensional pattern.

Light reflected back from the bar code symbol passes back through the window 52, impinges on the mirror 180, and is reflected to the collector 184. The collector concentrates the light and reflects it back to the photo detector 186. Decoding circuitry and/or a microprocessor (not shown) then decode the signals received by the photo detector 186, to determine the data represented by the bar code.

It might be thought that because the entire weight of the scan element 12 is taken by the Mylar film 38, the system is likely to be very vulnerable to shocks, for example if the user accidentally knocks or even drops the bar code scanner within which the module is contained. However, provision has been made for that contingency by way of an anti-shock feature which will now be described.

First, as may be seen in Figures 29 and 30, the lower end of the hanging bracket 34 is located within a channel 54 formed in the side support 18 of the chassis. As the Mylar film 38 flexes, the hanging bracket 34 moves back and forth within the channel 54. The Mylar film 34 is prevented from over-flexing by the walls of the channel 54 which act as stops. A similar arrangement (not visible in the drawings) is provided on the other side.

A second level of protection is provided by alignment pins 56, 58, best seen in Figure 28. Each pin comprises a threaded rear head portion 50, a reduced diameter smooth waist portion 62, and a smooth forward head portion 64.

In its operational position, shown in Figure 30, the waist portion 62 of the pin passes through a hole 68 in the hanging bracket 34, with the forward head portion 64 being received within a correspondingly-sized blind bore 70 within one side of the channel 54. The rear head portion 60 of the pin is screwed into and held in place by a threaded bore 66 which opens at its forward end into the channel 54 and at its rearward end into the rear surface of the rear wall 16. There is a similar arrangement on the other side (not shown) for the second alignment pin 58.

The diameter of the waist portion 62 of the pin is some 0.02 inches smaller than the diameter of the hole 68 in the hanging bracket. This provides sufficient tolerance for the Mylar to flex slightly during normal operation of the device. However, if the module is dropped the presence of the pin prevents over-stressing and perhaps breaking of the Mylar.

The alignment pins have a further function of assisting accurate positioning of the scan element 12 with respect to the chassis during assembly. During assembly, the scan element is brought up into approximately the correct position, and the alignment pins are then inserted as shown in Figure 29. At this point, the forward head portion 64 is a tight tolerance sliding fit both within the hole 68 in the hanging bracket and in the blind bore 70. This aligns the scan element to the pins and hence to the chassis. The scan element is then secured to the chassis, as previously described, using the screws 44, 46. The hangers 40, 42 provide a certain amount of adjustability or tolerance in positioning, thereby ensuring that the scan element can be attached to the chassis at the position defined by the alignment pins. The pins are then fully screwed into the threaded bores 66 until the end of the pin is flush with the rear face 16 of the chassis. At this point, as is shown in Figure 30, the forward head portion of the pin has been received within the bore 70, and the waist portion has moved up to its final position within the hole 68 of the hanging bracket.

It will be understood that each of the elements described above, or any two or more together, may also find a useful application in other types of constructions differing from those described.

While the invention has been illustrated and described as embodied in a variety of different arrangements, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the scope of the present invention,

as set out in the accompanying claims.

## Claims

1. A scan module for use in a scanner for reading indicia having parts of differing light reflectivity, the scan module comprising:
   a) a frame;
   b) a scanning component mounted to the frame for oscillatory motion, the scanning component including an optical element for directing light in a scanning pattern across an indicia to be read, the scanning component having an aperture therein;
   c) an anti-shock member, passing through the aperture in the scanning component, the anti-shock member being smaller in cross section than the size of the aperture, thereby providing clearance for the scanning component to oscillate in use, but preventing excessive movement of the scanning component with respect to the frame in the event that the module is subjected to a mechanical shock.

2. A method of assembling a scan module for use in a scanner for reading indicia having parts of differing reflectivity, the scan module comprising: a frame; a scanning component to be mounted to the frame for oscillatory motion, the scanning component including an optical element for directing light in a scanning pattern across an indicia to be read, the scanning component having an aperture therein; and an anti-shock pin having a first head portion, a second portion, and a waist portion having a smaller cross section than the first and second head portions; the method comprising:
   a) positioning the scanning component adjacent to the frame;
   b) partially inserting the pin in to the frame so that the second head portion passes through the aperture and extends from the aperture in to a correspondingly-shaped bore in the frame, thereby aligning the scanning component with respect to the frame;
   c) securing the scanning component to the frame;
   d) continuing insertion of the pin in to the frame so that the waist portion of the pin becomes located within the aperture, thereby providing clearance for the scanning component to oscillate in use, but preventing excessive movement of the scanning component with respect to the frame in the event that the module is subjected to a mechanical shock.

3. A scan module for use in a scanner for reading indicia having parts of differing light reflectivity, the scan module comprising:
   a) a frame;
   b) a scanning component comprising a bracket mounted to the frame by flexible support means for oscillatory motion, the bracket carrying an optical element for directing light in a scanning pattern across an indicia to be read;
   c) an electromagnetic coil mounted to the frame;
   d) magnet means secured to the bracket adjacent the coil;
   and
   e) the bracket further including a counterweight portion balancing the mass of the optical element at the flexible support means, the counterweight portion at least partially overlying the coil.

4. A scan module for use in a scanner for reading indicia having parts of differing light reflectivity, the scan module comprising:
   a) a frame;
   b) a scanning component comprising a main bracket mounted to the frame by flexible support means for oscillatory motion, the main bracket carrying an optical element for directing light in a scanning pattern across an indica to be read, the main bracket having an aperture therein;
   c) an electromagnetic coil mounted to the frame;
   d) magnet means, secured to the bracket adjacent to the coil;
   e) the bracket further including a counterweight portion balancing the mass of the optical element at the flexible support means, the counterweight portion at least partially overlying the coil;
   and
   f) an anti-shock member passing through the aperture in the main bracket, the member being smaller in cross section than the size of the aperture, thereby providing clearance for the scanning component to oscillate in use, but preventing excessive movement of the scanning component with respect to the claim in the event that the module is subjected to a mechanical shock.

5. A scanning system operable both in portable and fixed modes for reading barcode symbols, comprising:
   means for determining whether operation is in a fixed or portable mode; and
   means for adapting the scan pattern to an

optimized pattern for such mode of operation.

6. A system for reading coded indicia, comprising:
an electro-optical reader within a portable housing having a means for enabling a human operator to hold and aim the reader at indicia to be read, the reader including a light source for generating a light beam, a light detector for receiving light reflected from said indicia and in response generating an electrical signal, and means for converting said electrical signal to data representing information content of said indicia;
a stationary fixture having a means for supporting the portable housing of the reader when not held by the operator; and
scan control means for controlling the light beam to scan the indicia with a first scan pattern for reading the coded indicia independently of pattern orientation when the portable housing is mounted in said fixture and a second scan pattern optimized for reading a prescribed classification of coded indicia when the portable housing is separated from said fixture.

7. A system for reading coded indicia, comprising:
an electro-optical reader within a portable housing having a means for enabling a human operator to hold and aim the reader at indicia to be read, the reader including a light source for generating a light beam, a light detector for receiving light reflected from said indicia and responsively generating an electrical signal, and means for converting said electrical signal to data representing information content of said indicia;
a stationary fixture having a means for supporting the portable housing of the reader when not held by the operator; and
scan control means for controlling the light beam to scan the indicia with different prescribed scan patterns in response to the information content of the indicia and whether the portable housing is separated from or mounted in said fixture.

8. A device for reading barcode symbols, or the like, comprising:
a light source for generating a light beam and directing the beam toward a symbol to be read;
a light detector for receiving light reflected from said symbol and, in response, generating an electrical signal;
means for converting said electrical signal to data representing the information content of said barcode symbol; and
scan control means for controlling the light beam to scan the symbol with a prescribed scan pattern to develop control information, and thereafter to increase a dimension of the scan pattern at a rate dependent upon said control information.

9. A method of reading barcode symbols, comprising the steps of:
directing a light beam toward a symbol to be read;
executing an aim mode of operation by controlling said light beam to scan said symbol with a visible scan pattern that is relatively small compared to the symbol;
receiving light reflected from said symbol, and producing first data identifying an attribute of said symbol; and
executing a decode mode of operation by producing second data corresponding to the symbol while increasing a dimension of said scan pattern at a rate and to a size dependent upon said first data.

10. A device for reading barcode symbols, or the like, comprising:
a light source for generating a light beam and directing the beam toward a symbol to be read;
scan control means for controlling the light beam to scan the symbol with a scan pattern having the form of a raster that precesses among successive frames;
a light detector for receiving light reflected from said symbol and, in response, generating an electrical signal; and
means for converting said electrical signal into data corresponding to content of said symbol.

11. A method of reading barcode symbols, or the like, comprising the steps of:
generating a light beam and directing the beam toward a symbol to be read;
controlling the light beam to traverse the symbol with a scan pattern having the form of a raster that precesses among successive frames so as to be capable of decoding one-dimensional barcodes of varying horizontal orientation and of decoding two-dimensional barcodes despite any arcuate nonlinearity (droop) of the raster pattern;
receiving light reflected from said symbol and responsively producing an electrical signal; and
converting said electrical signal into data corresponding to content of said symbol.

12. A device for reading barcode symbols, or the like, comprising:
a light source for generating a light beam and directing the beam toward a symbol to be read;
scan control means for controlling the light beam to scan the symbol with a rotating Lissajous scan pattern;
a light detector for receiving light reflected from said symbol and, in response, generating an electrical signal; and
means for converting said electrical signal into first data corresponding to an attribute of said barcode symbol;
said scan control means including further means for converting the rotating Lissajous scan pattern to a raster scan pattern depending upon said barcode symbol attribute.

13. A method of reading barcode symbols, comprising the steps of:
directing a light beam toward a symbol to be read;
executing an aim mode of operation by controlling said light beam to scan said symbol with a visible scan pattern in the form of a rotating Lissajous pattern;
receiving light reflected from said symbol, and producing first data identifying an attribute of said symbol including whether said symbol represents a one-dimensional barcode symbol or a two-dimensional barcode symbol; and
executing a decode mode of operation such that

14. An optical scanning assembly, comprising:
a housing;
a source within said housing for emitting a light beam to be reflected from a symbol to be scanned;
a photodetector positioned within said housing for receiving light reflected from said symbol and responsively producing an electrical signal;
an optical element positioned within the housing in a path of said light beam;
a permanent magnet mounted to a support member and producing a magnetic field;
an electric coil mounted with said optical element and axially displaced from said support member; and
a plurality of semi-rigid electrically conducting wires interconnecting said coil and said support member such that AC drive current applied to said coil through said wires causes said coil to generate an electromagnetic field for interaction with the magnetic field of said permanent magnet to produce oscillatory motions of said optical element.

15. An optical scanning assembly, comprising:
a housing;
a source within said housing for emitting a light beam to be reflected from a symbol to be scanned;
a photodetector positioned within said housing for receiving light reflected from said symbol and responsively producing an electrical signal; and
an optical scanning element in said housing and formed by the following:
an optical element positioned in a path of said light beam,
a cylindrical permanent magnet mounted to a support member of magnetically permeable material for producing a magnetic field, said cylindrical magnet having an open end opposing said support member,
a cylindrical electric coil mounted to said support member, surrounded by said permanent magnet and itself surrounding a core of said magnetically permeable material,
a flexible membrane mounted to and spanning the open end of said cylindrical permanent magnet,
a metal plate of small mass attached to said membrane in proximity to said electric coil and said core,
an optical element mounted for pivotal movement, and displaced from but axially aligned with said metal plate, and
a coupling element of small mass interconnecting said optical element and said metal plate;
whereby AC drive current applied to said coil causes said coil to generate an electromagnetic field for interaction with the magnetic field of said permanent magnet to produce oscillatory motions of said optical element with repetitive flexing of said diaphragm.

16. An optical scanning assembly, comprising:
a housing;
a source within said housing for emitting a light beam to be reflected from a symbol to be scanned;
a photodetector positioned within said housing for receiving light reflected from said symbol and responsively producing an electrical signal; and
an optical scanning element in said housing and formed by the following:
an optical element positioned in a path of said light beam,
an electric coil of cylindrical shape mounted to a support member and producing a

varying magnetic field in response to an AC current,

a permanent magnet mounted in alignment with a central axis, and adjacent one end, of said coil,

a reflector for light emitted from said light source and of mass substantially less than the mass of said permanent magnet, and

an arcuate bracket of flexible material interconnecting said permanent magnet and said reflector.

17. An optical scanner module for directing a light beam in a pattern to scan a symbol, comprising:

a frame formed of flexible material and having first and second opposed ends;

a pair of parallel, slightly spaced apart wires connected to and maintained taut between the ends of said frame;

mounted to said pair of taut wires approximately centrally between the ends of said bracket, a subassembly including an optical element for directing the light beam, and a permanent magnet coupled to said optical element and developing a magnetic field; and

an electromagnetic coil for receiving AC drive current to generate an electromagnetic field for interaction with the magnetic field of said permanent magnet to produce oscillatory motion of said optical element in a first scanning direction.

18. A bar code reader, comprising:

a light beam scanner generating a light beam directed toward a symbol to be read and moving said light beam along said symbol in an omnidirectional scanning pattern;

a light detector receiving reflected light from said symbol and generating electrical signals responsive to said reflected light; and

means for controlling said scanning pattern in response to said electric signals.

19. A method of scanning bar code symbols or the like, comprising the steps of:

providing a relatively bright, rosette scanning pattern for enabling a user to aim and direct the beam toward a bar code symbol to be read;

scanning said symbol;

detecting light reflected from the symbol and generating an electrical signal in response to said reflected light; and

modifying the radial diameter of said scan pattern in response to said electrical signal.

20. A system for reading bar code symbols or the like, comprising:

scanning means for generating a laser beam directed toward a target and producing a first scanning pattern

that enables a user to manually aim and direct the beam to the location desired by the user and a relatively larger second scanning pattern in the form of a Lissajous pattern that sweeps an entire symbol to be read,

means for changing the scanning pattern produced by said scanning means from said first scanning pattern to said second scanning pattern; and

21. A system for reading bar code symbols or the like, comprising;

scanning means for generating a laser beam directed toward a target and producing a first omnidirectional scanning pattern for a first period of time and subsequently an angularly offset second omnidirectional scanning pattern that sweeps the entire height of a symbol to be read;

means for changing the scanning pattern from said first to said second pattern; and

detection means for receiving reflected light from said symbol to produce electrical signals corresponding to data represented by said symbol.

22. A method for reading bar code symbols or the like, comprising the steps of:

generating a laser beams directed toward a target and producing a first scanning pattern that enables the user to manually aim and direct the beam to the location desired by the user and a relatively larger second scanning pattern in the form of an omnidirectional pattern that sweeps an entire symbol to be read;

changing from said first scanning pattern to said second scanning pattern; and

receiving reflected light from said symbol to produce an electrical signal corresponding to data represented by said symbol.

23. A method for reading bar code symbols or the like, comprising the steps of generating a laser beam directed toward a target and producing a first scanning pattern that has a reflectivity on the target that enables a user to manually aim and direct the beam to a desired location on the target, generating a sequence of different subsequent scanning patterns that each are rotationally offset with respect to the preceding scanning pattern, including a scanning pattern that sweeps the entire symbol to be read, and receiving reflected light from the symbol to

produce an electrical signal corresponding to data represented by said symbol.

24. A bar code reader, comprising:

a light beam scanner generating a light beam directed toward a symbol to be read and moving said light beam along said symbol in a prescribed line scanning pattern;

a light detector receiving reflected light from said symbol and generating electrical signals responsive to said reflected light; and

means for controlling the angular orientation of said scanning pattern with respect to a center of rotation thereof in response to said electrical signals.

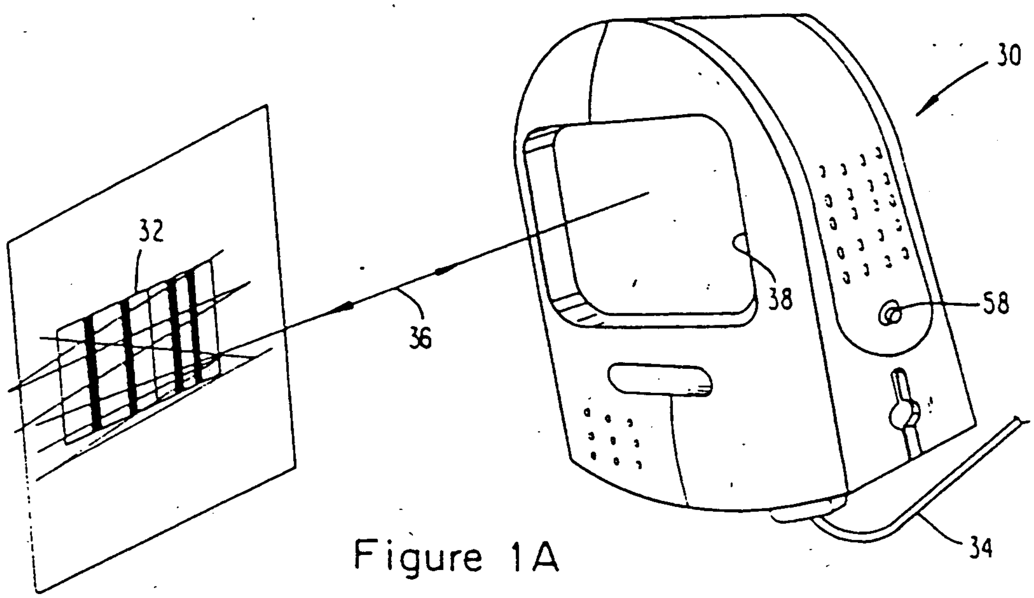



Figure 1A

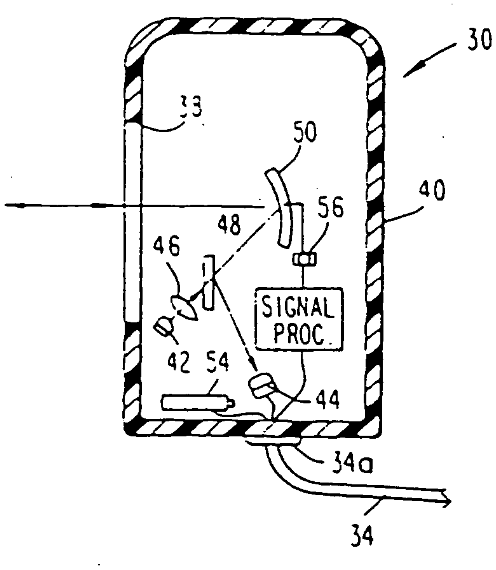



Figure 1B

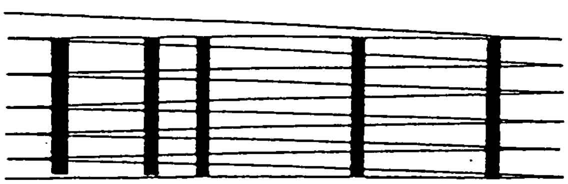


Figure 2A
(PRIOR ART)

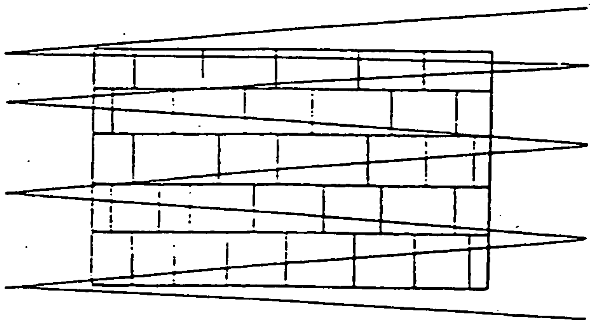


Figure 2B
(PRIOR ART)

ROTATING LISSAJOUS

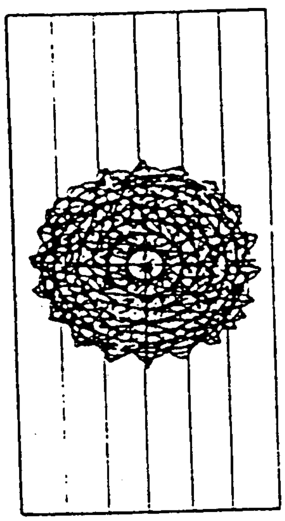


Figure 4A

RASTER

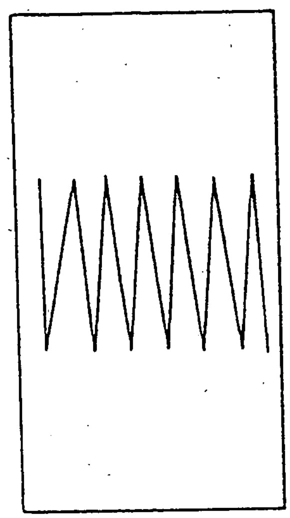


Figure 4B

ENLARGED RASTER

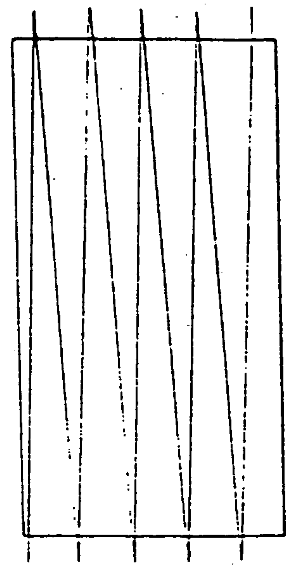


Figure 4C

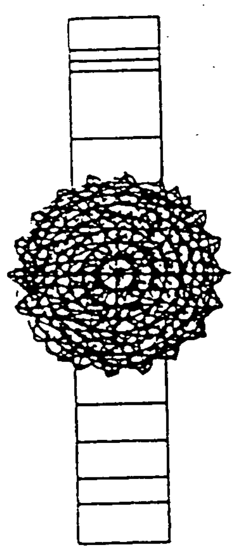


Figure 3A

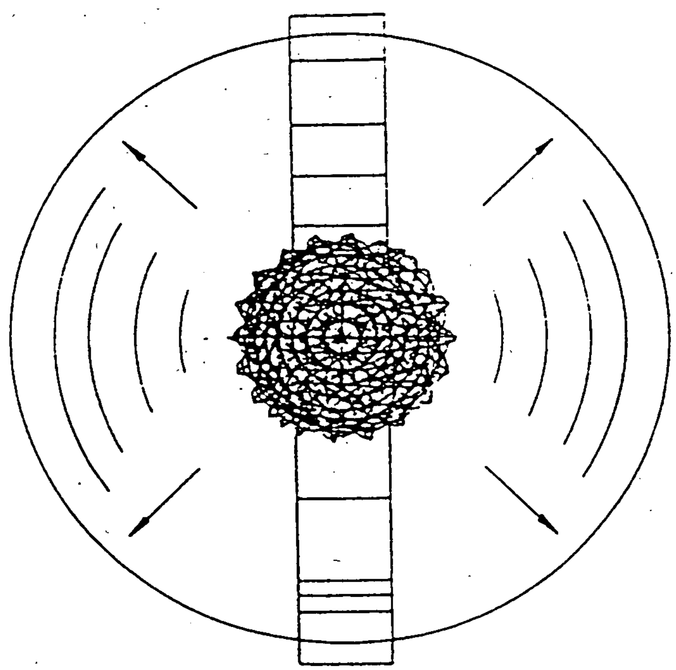


Figure 3B

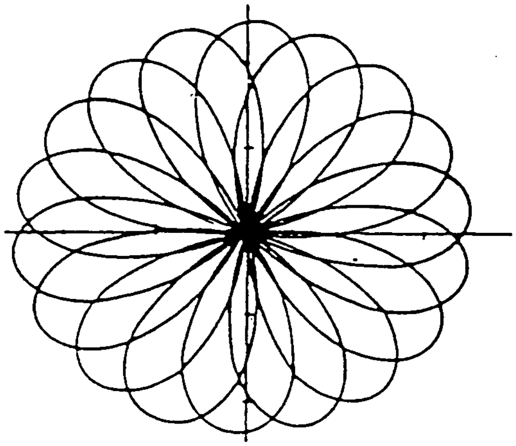


Figure 5A

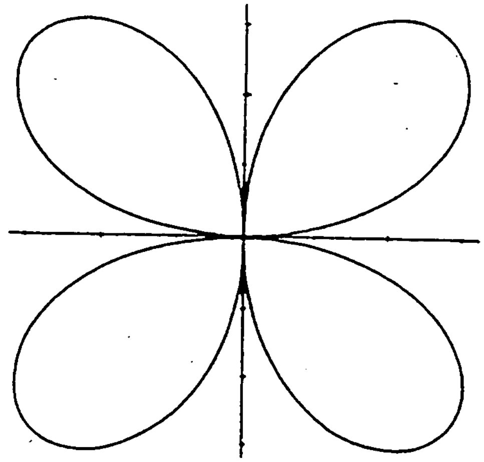


Figure 5B

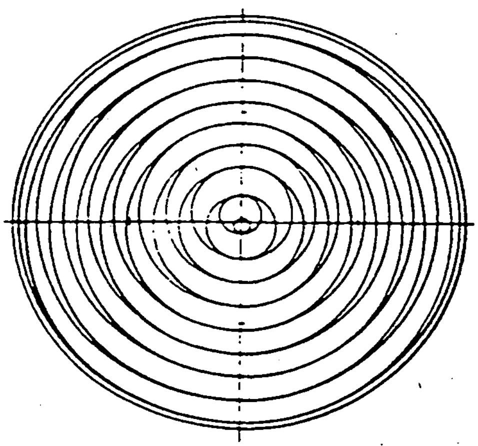


Figure 5C

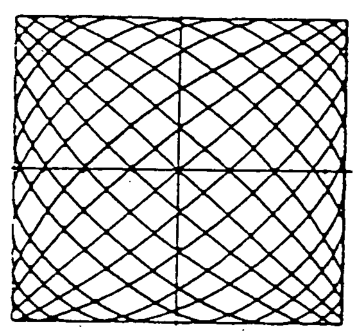


Figure 5D

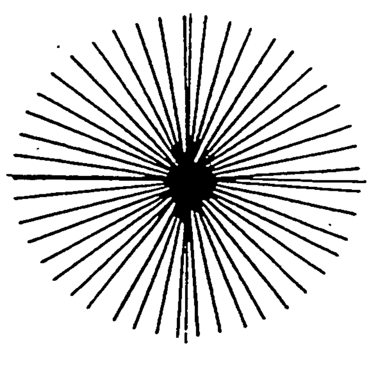


Figure 5F

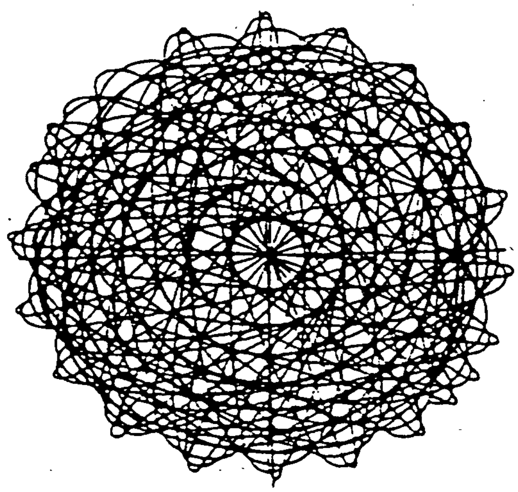


Figure 6

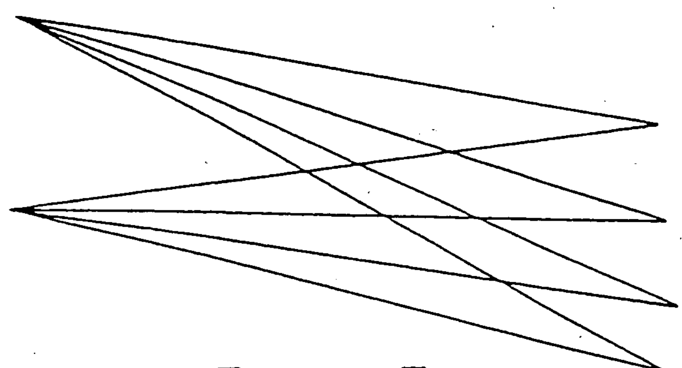


Figure 7

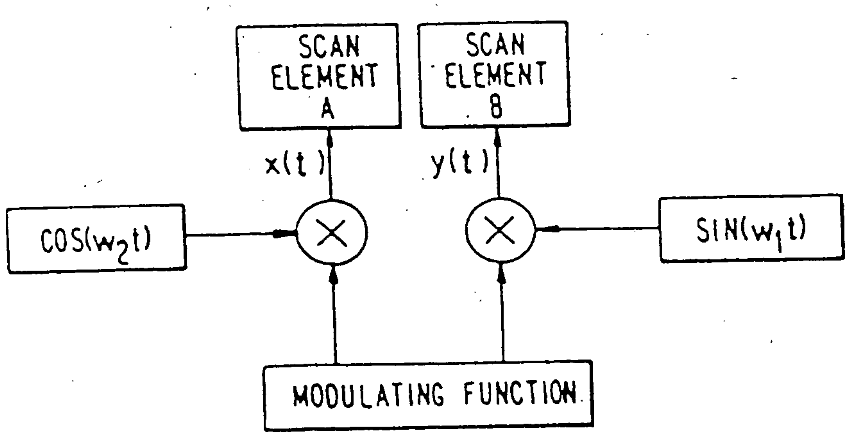



Figure 8

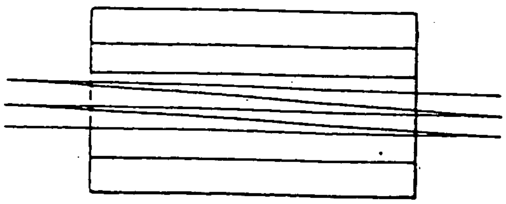


Figure 9A

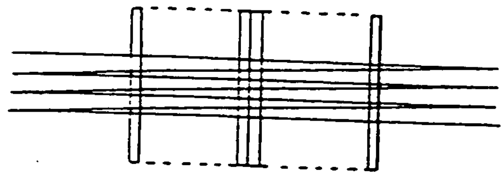


Figure 9D

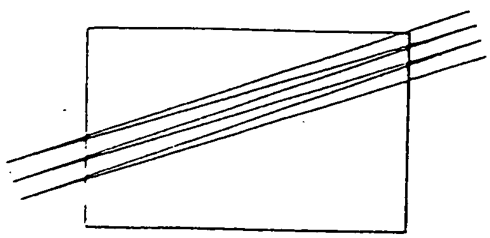


Figure 9B

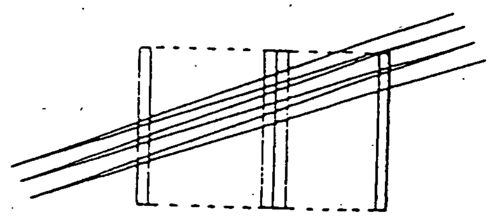


Figure 9E

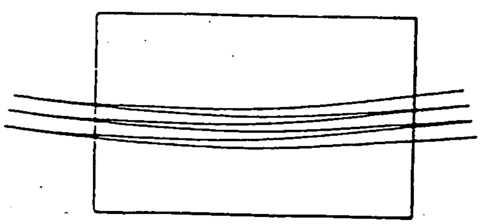


Figure 9C

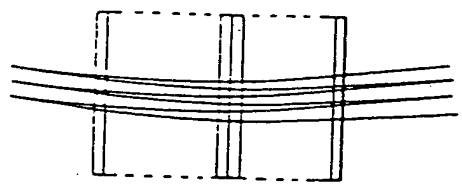


Figure 9F

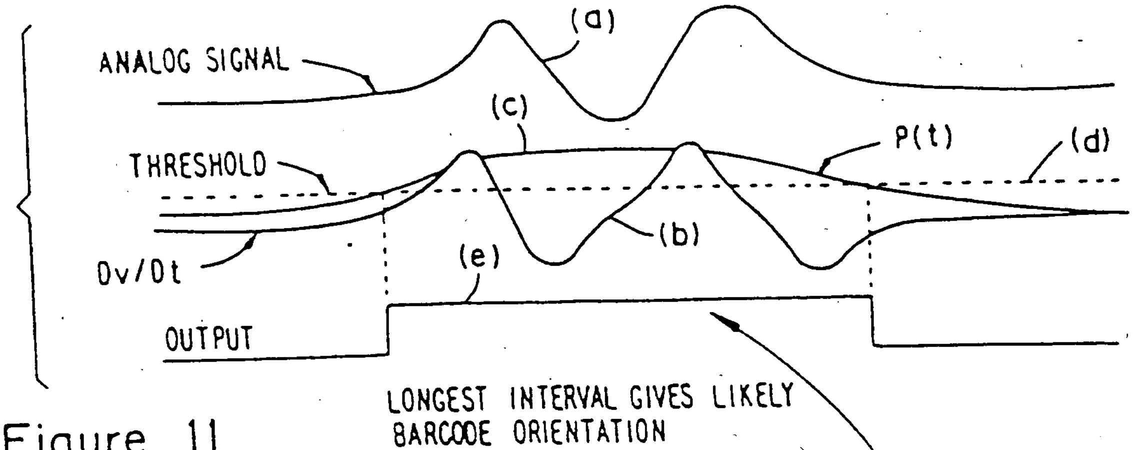



Figure 11

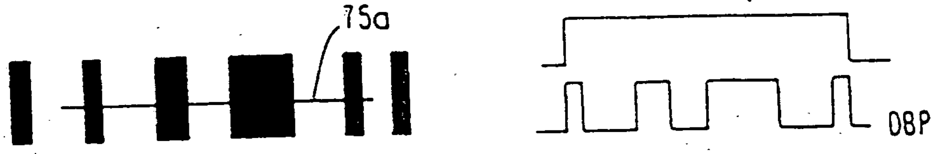



Figure 10A

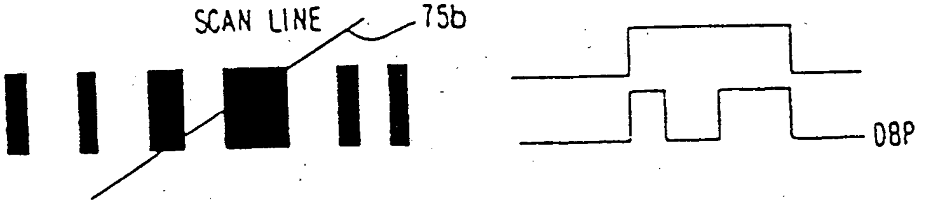



Figure 10B

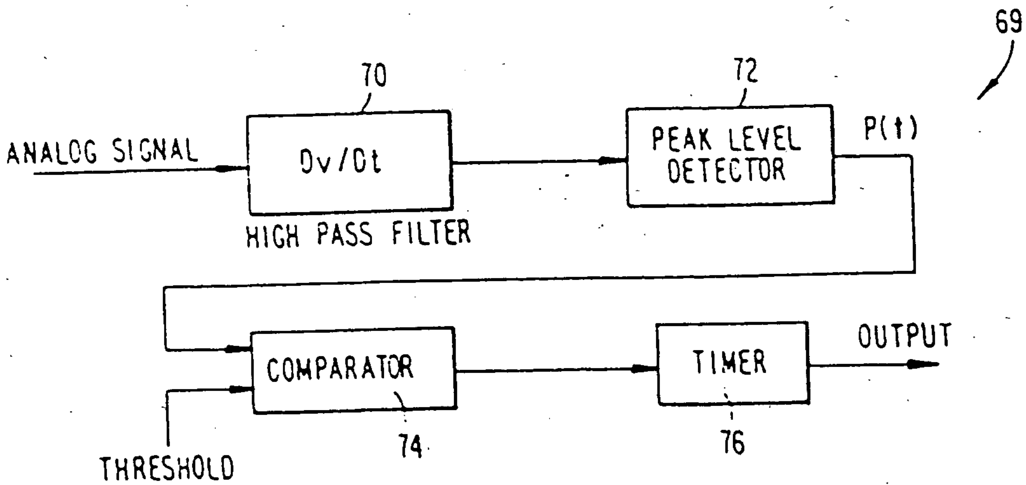



Figure 12

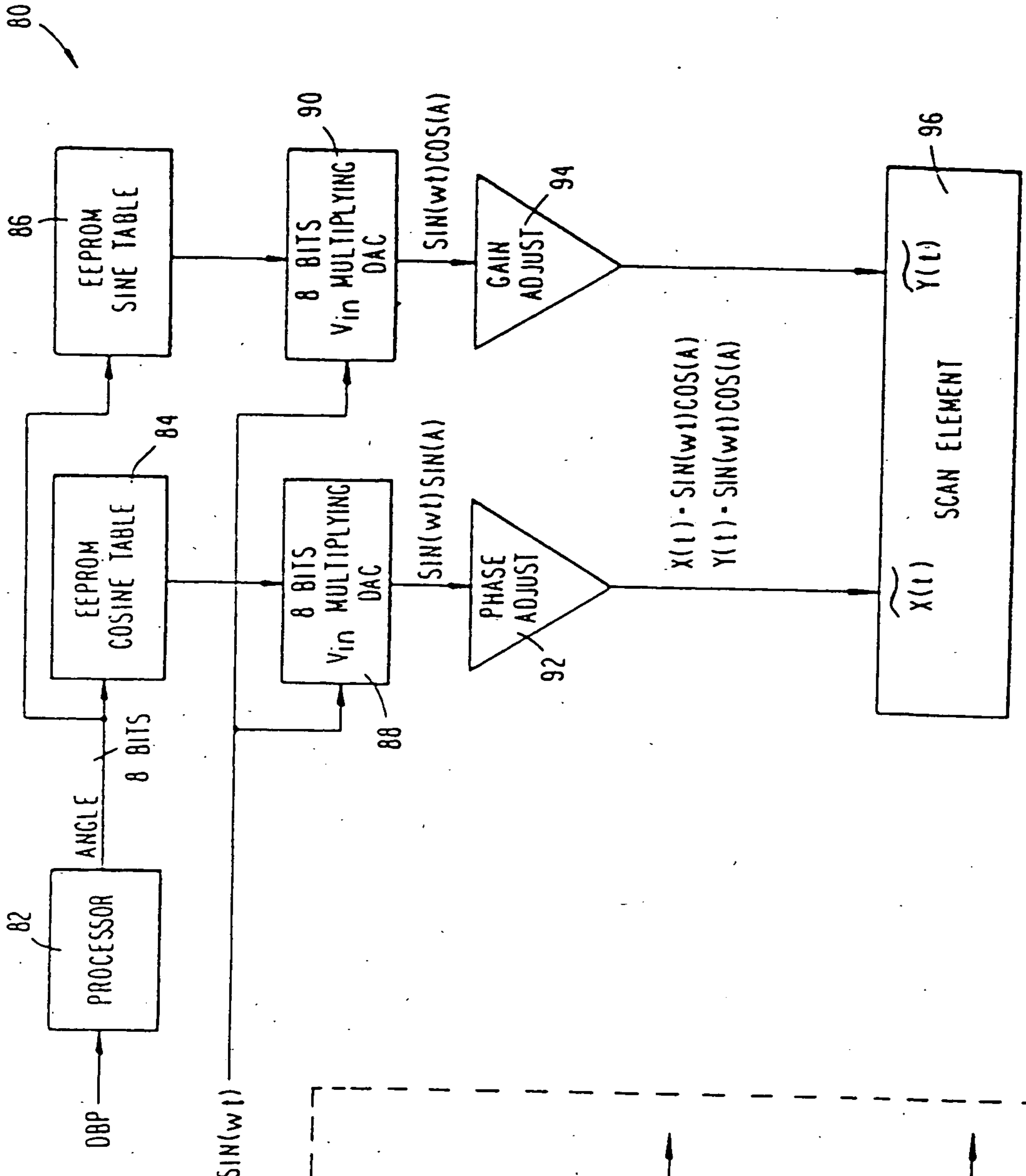



Figure 13A

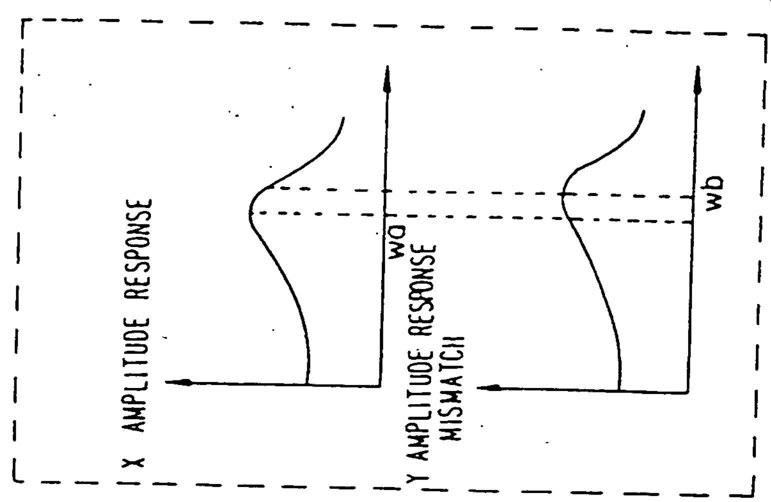



Figure 13B

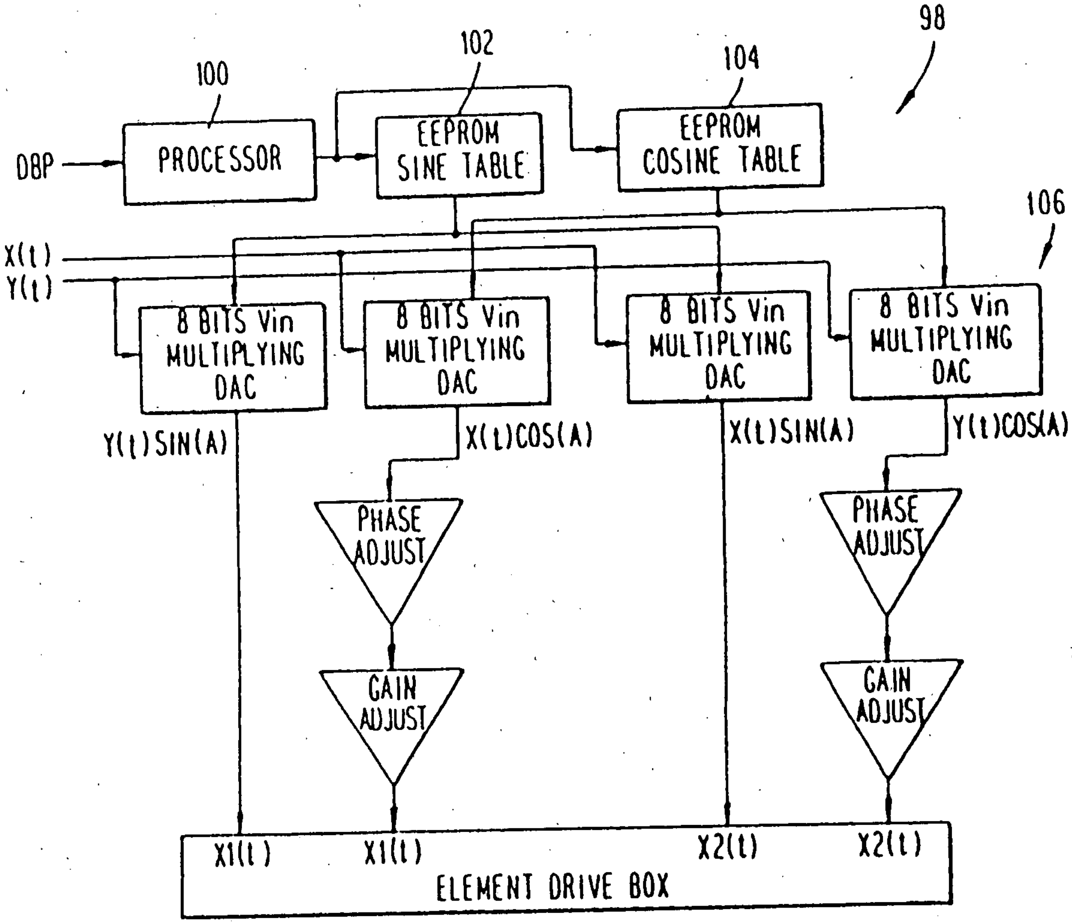



Figure 14

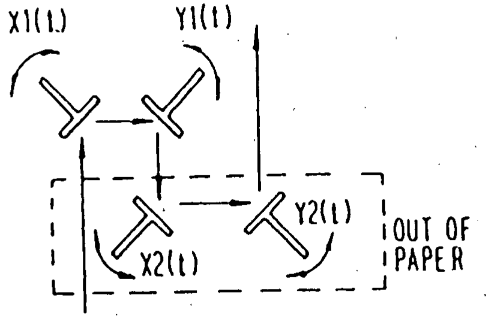



Figure 17A

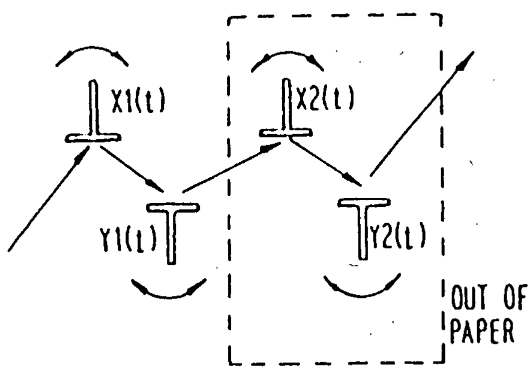



Figure 17B

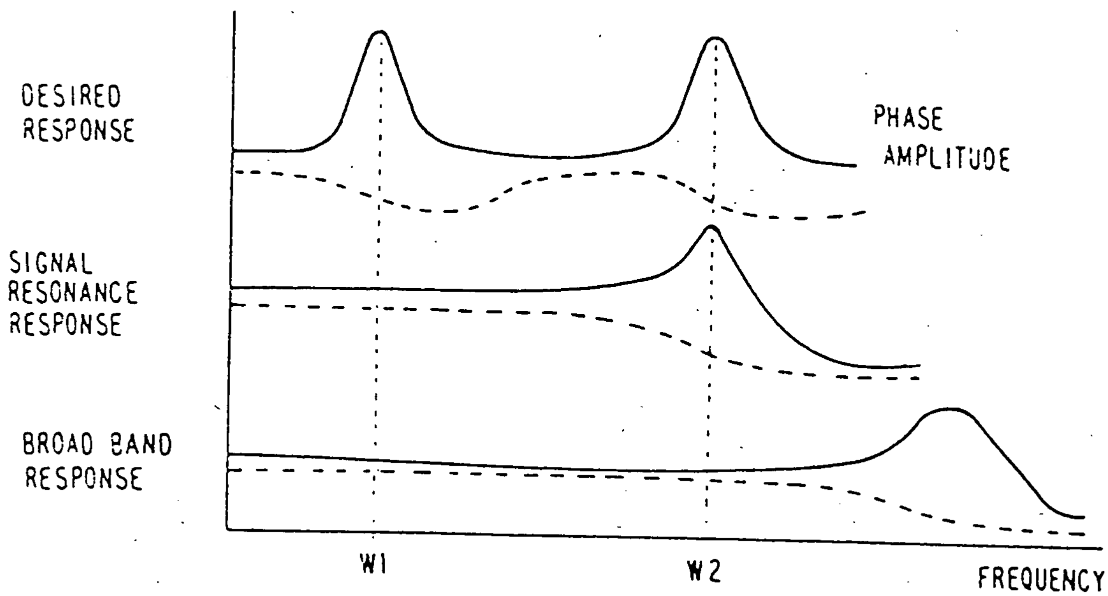

DESIRED RESPONSE
PHASE
AMPLITUDE
SIGNAL RESONANCE RESPONSE
BROAD BAND RESPONSE
W1
W2
FREQUENCY

Figure 15

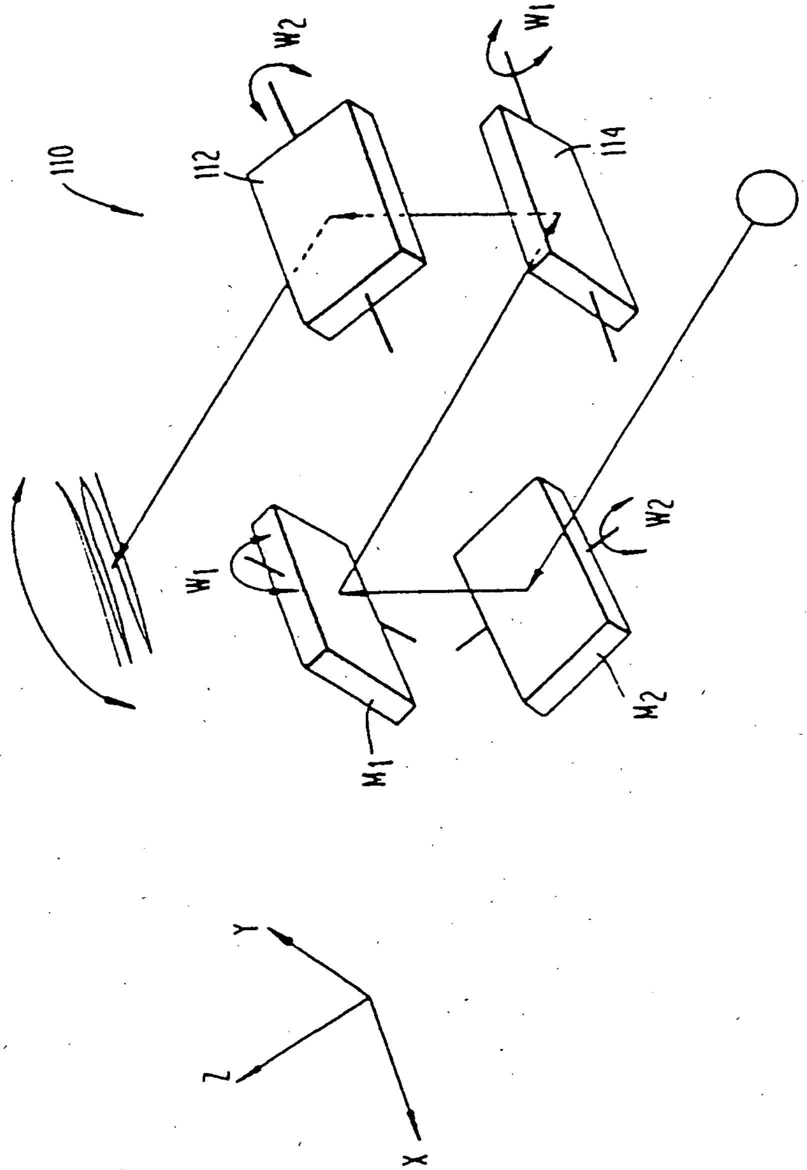



Figure 16

Figure 18

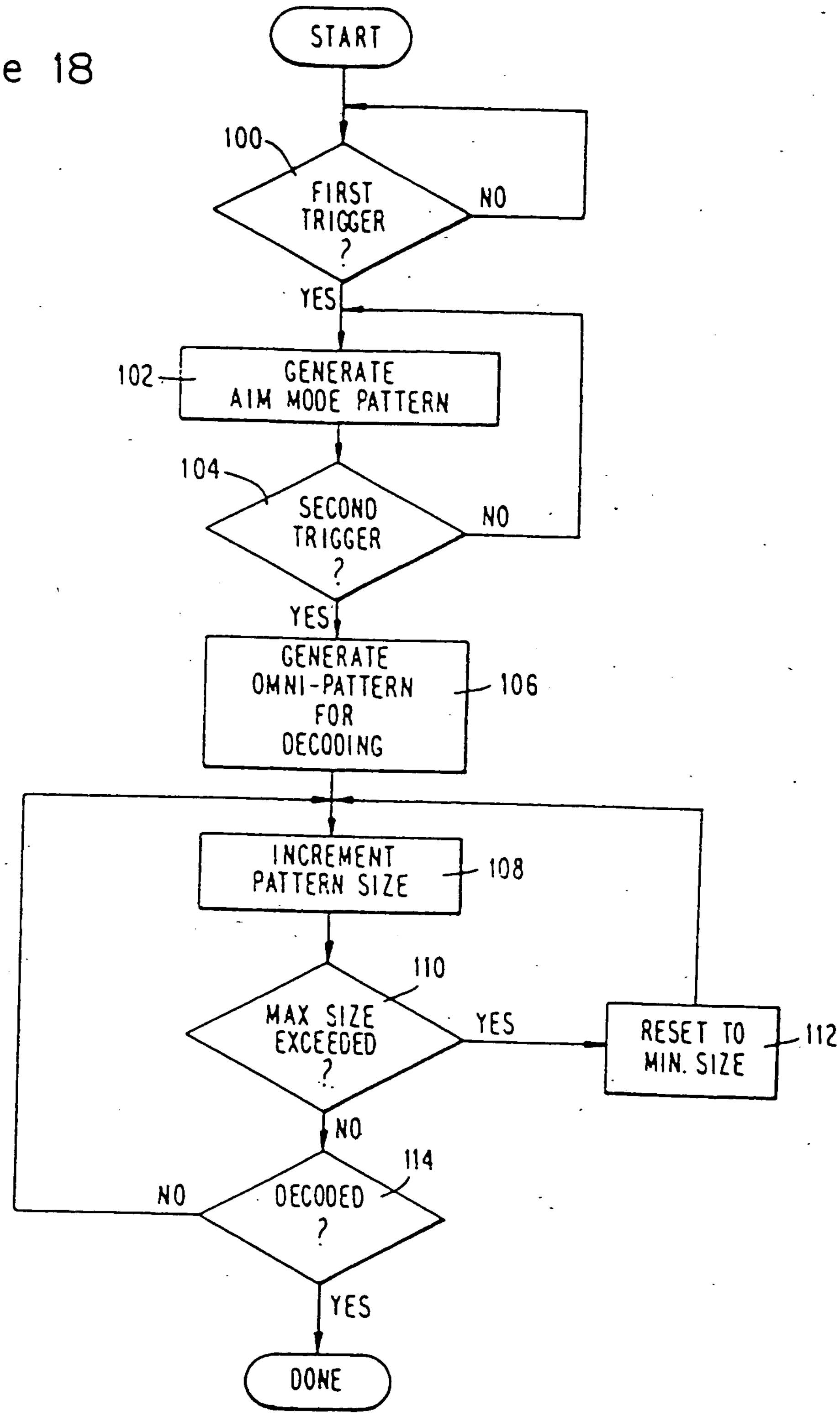
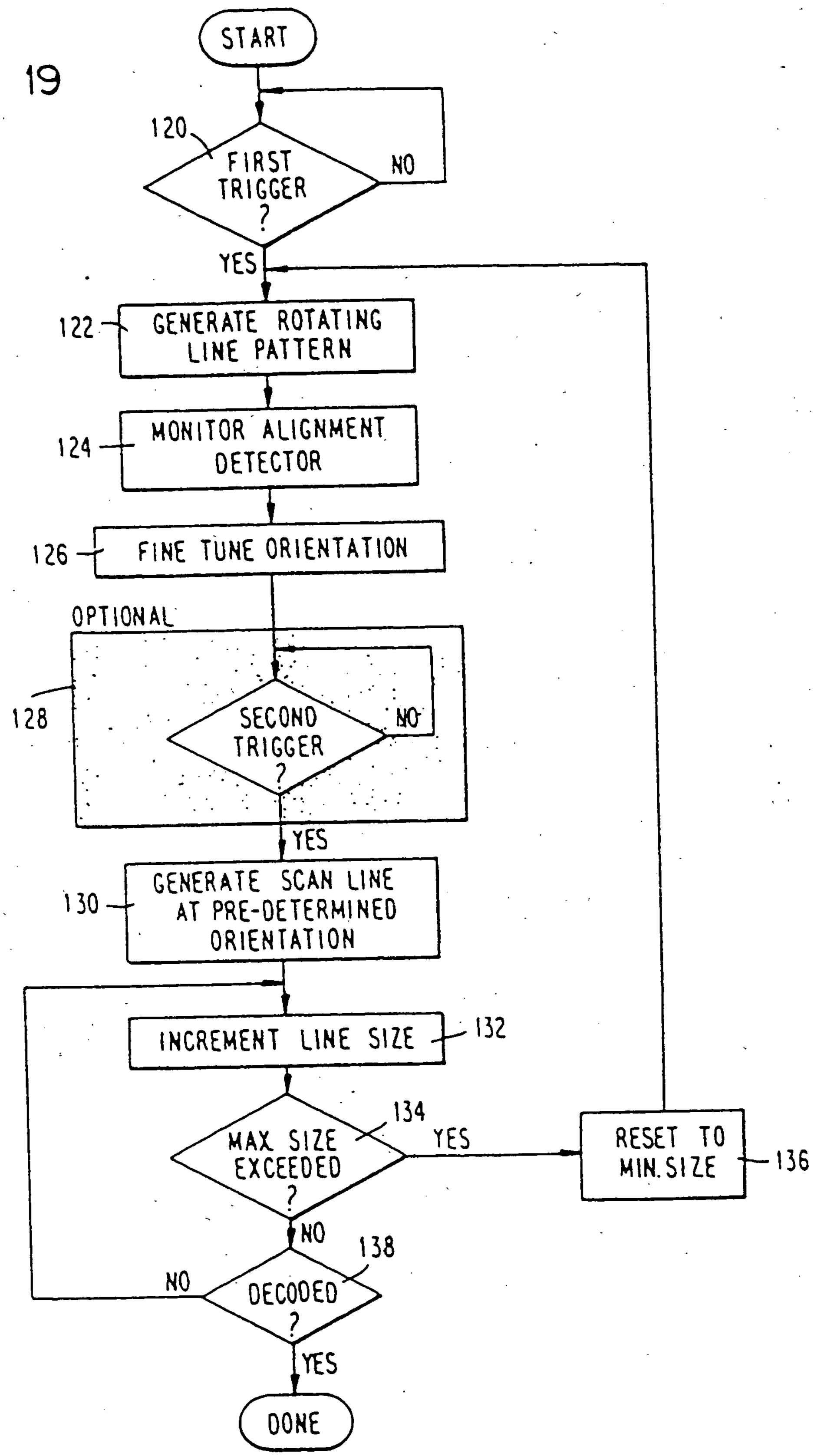

START
100
FIRST TRIGGER ?
NO
YES
102
GENERATE AIM MODE PATTERN
104
SECOND TRIGGER ?
NO
YES
GENERATE OMNI-PATTERN FOR DECODING
106
INCREMENT PATTERN SIZE
108
110
MAX SIZE EXCEEDED ?
YES
RESET TO MIN. SIZE
112
NO
114
DECODED ?
NO
YES
DONE

Figure 19


START
120
FIRST TRIGGER ?
NO
YES
122
GENERATE ROTATING LINE PATTERN
124
MONITOR ALIGNMENT DETECTOR
126
FINE TUNE ORIENTATION
OPTIONAL
128
SECOND TRIGGER ?
NO
YES
130
GENERATE SCAN LINE AT PRE-DETERMINED ORIENTATION
INCREMENT LINE SIZE
132
134
MAX SIZE EXCEEDED ?
YES
RESET TO MIN.SIZE
136
NO
138
NO
DECODED ?
YES
DONE

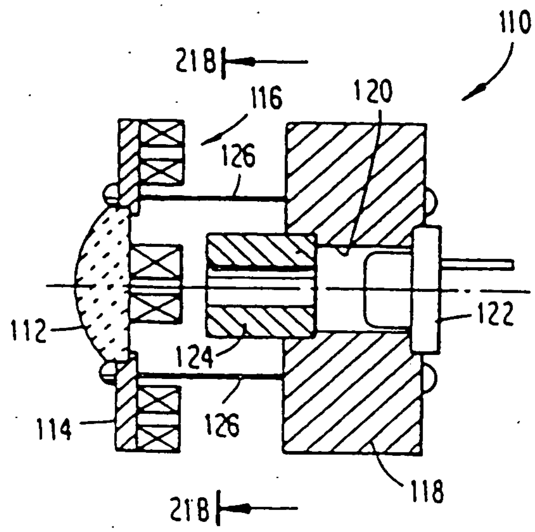



Figure 21A

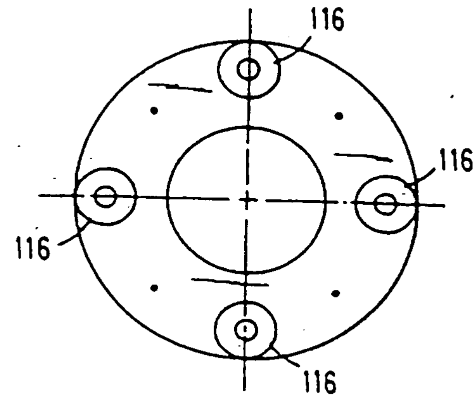



Figure 21B

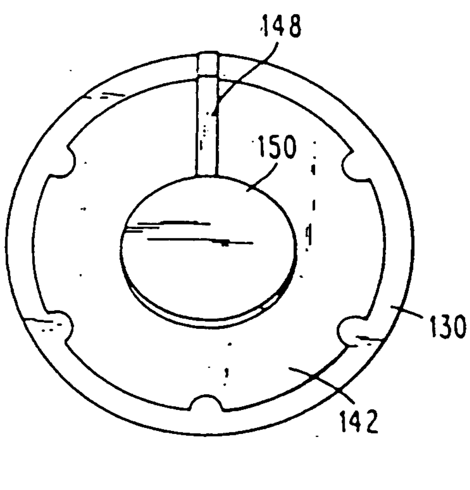



Figure 20B

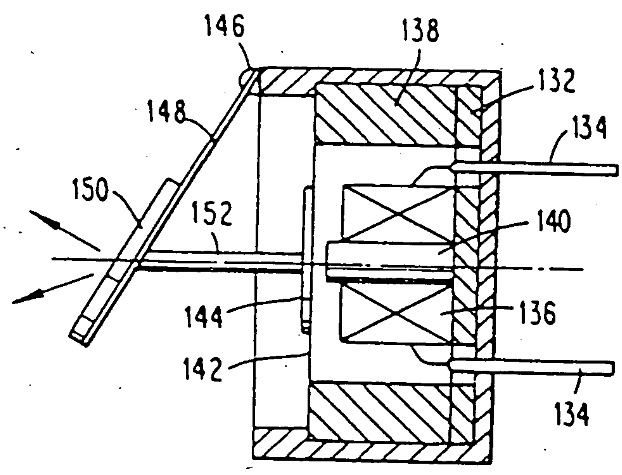



Figure 20A

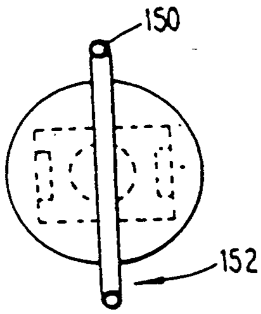



Figure 22B

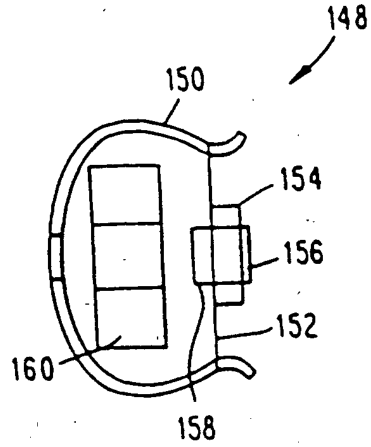



Figure 22A

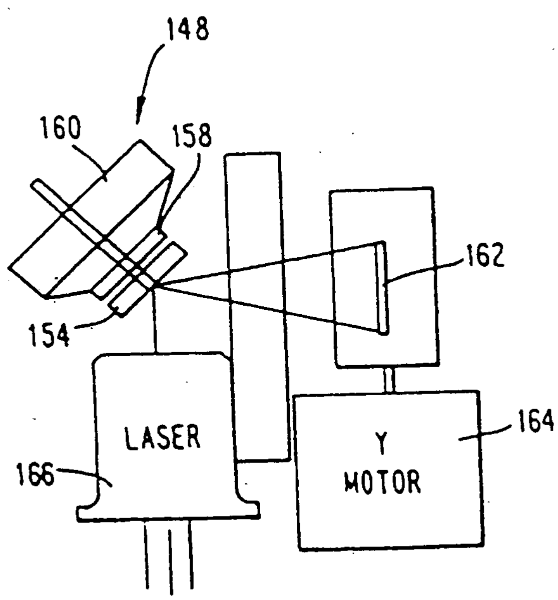



Figure 23

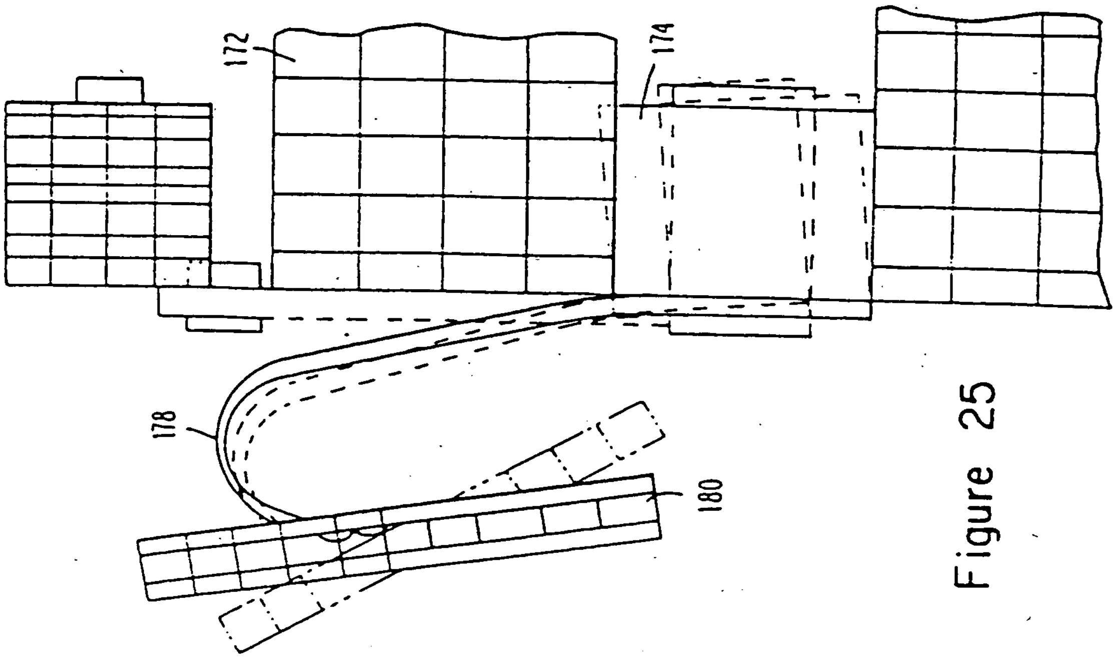



Figure 25

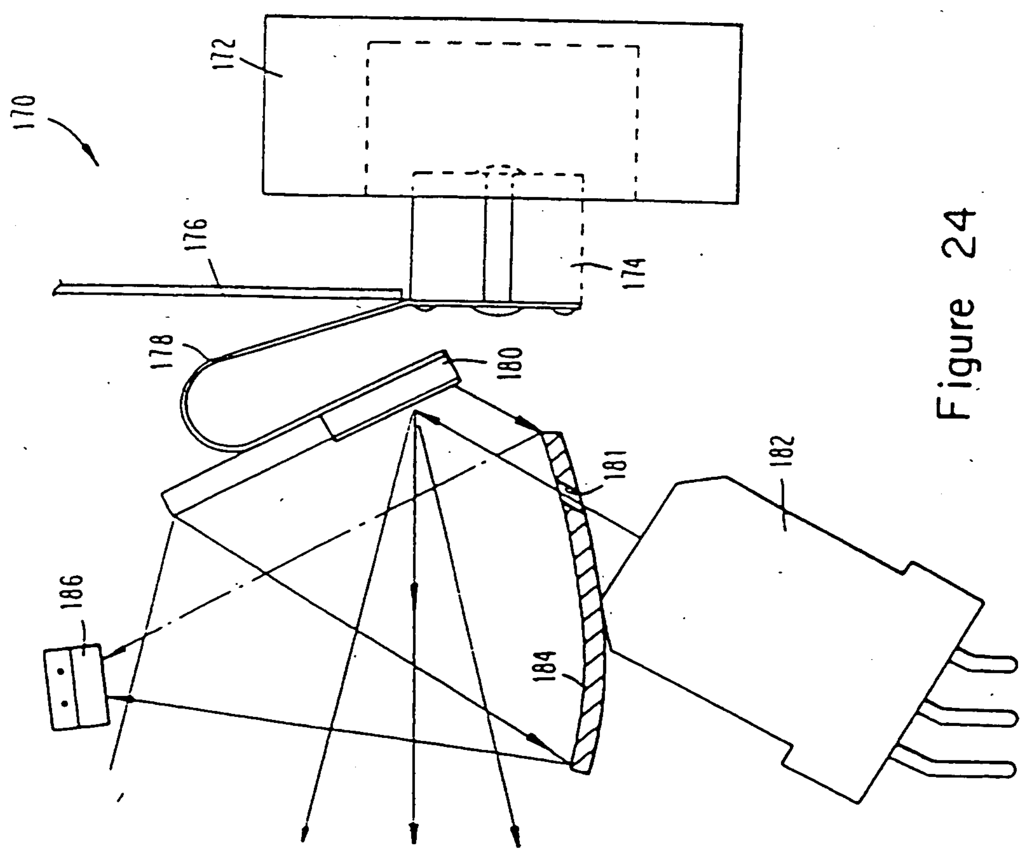



Figure 24

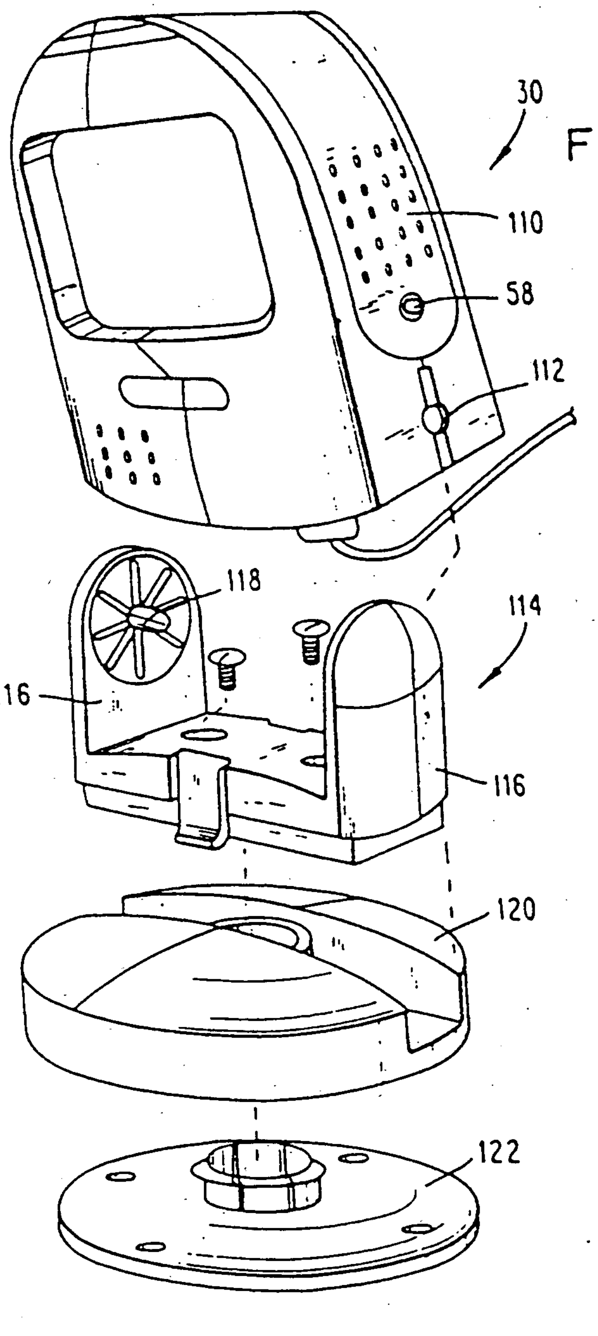



Figure 26A

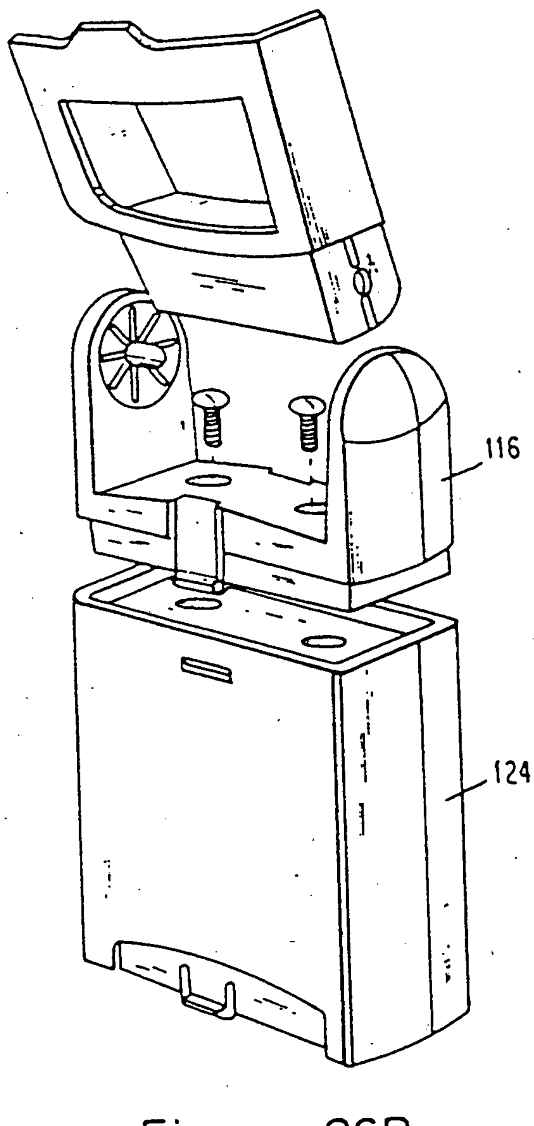
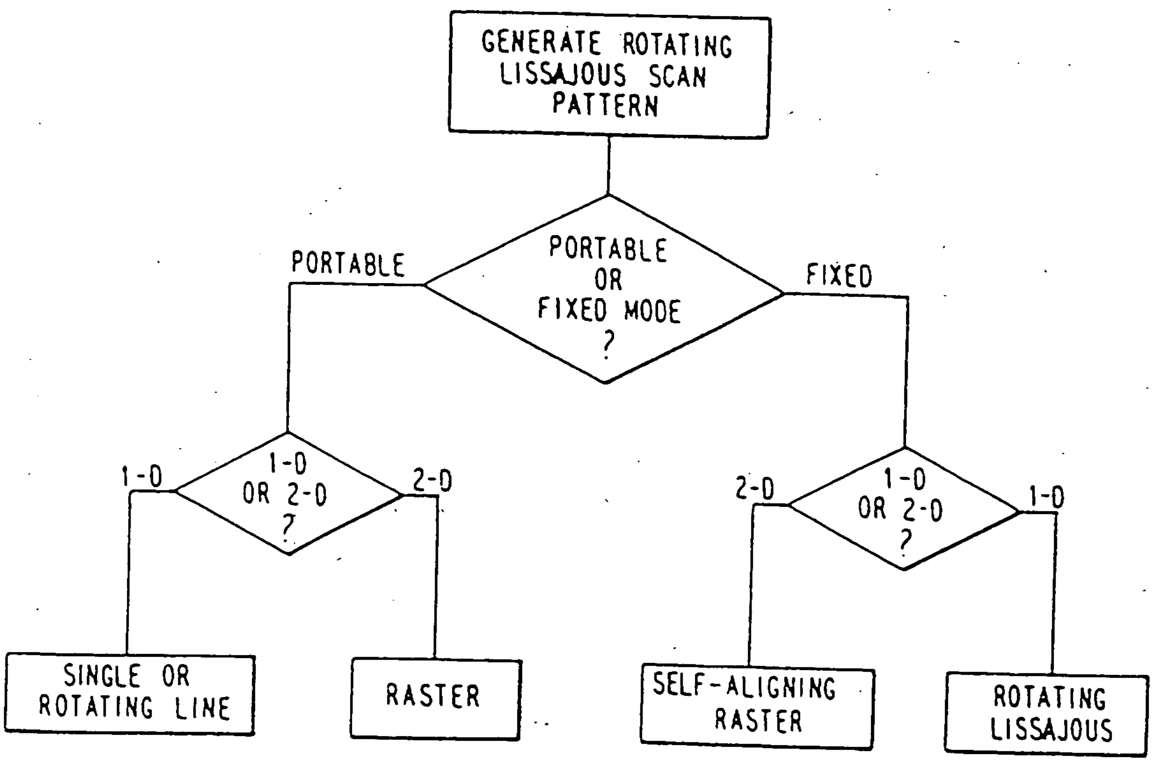



Figure 26B

Figure 27


GENERATE ROTATING LISSAJOUS SCAN PATTERN
PORTABLE OR FIXED MODE ?
PORTABLE
FIXED
1-D OR 2-D ?
1-D
2-D
1-D OR 2-D ?
2-D
1-D
SINGLE OR ROTATING LINE
RASTER
SELF-ALIGNING RASTER
ROTATING LISSAJOUS

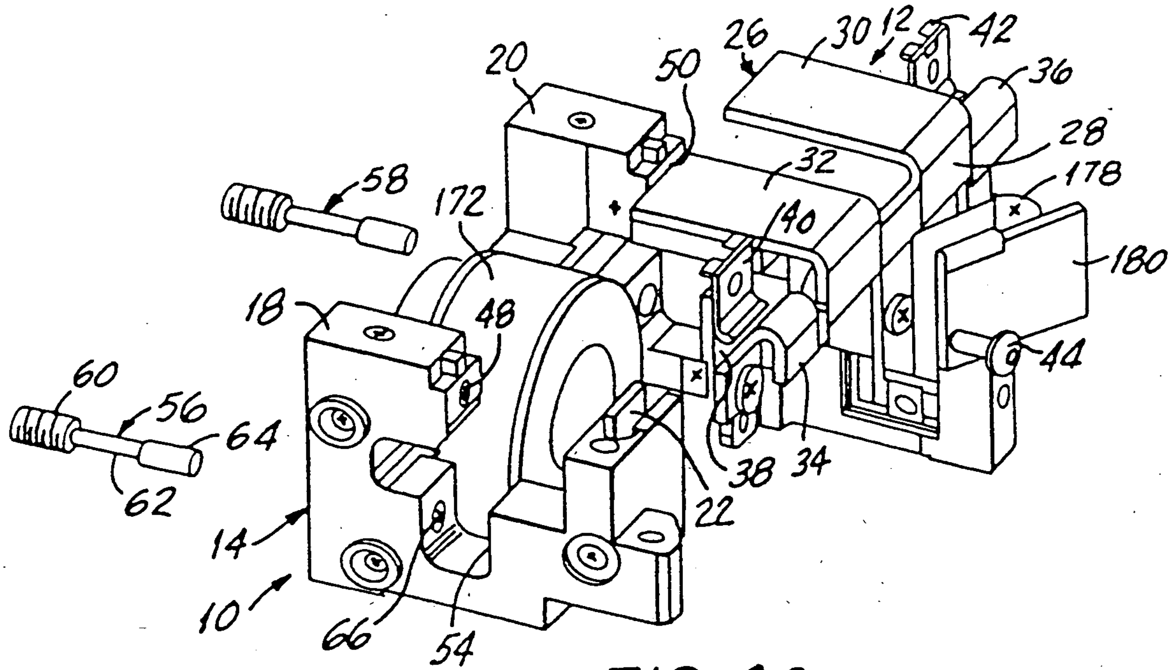

20
50
26
30
12
42
36
28
32
178
58
172
140
180
18
48
44
60
56
64
38
34
22
62
14
10
66
54

FIG. 28

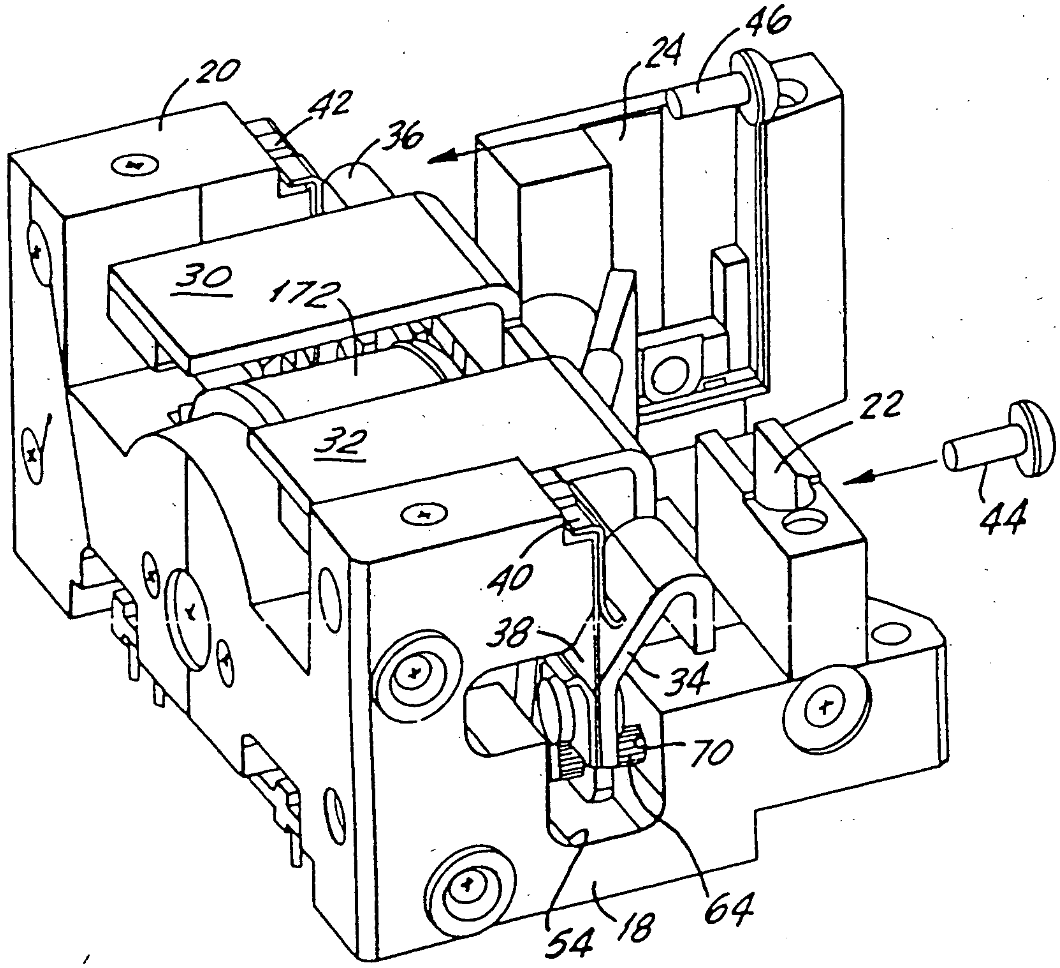

20
42
36
24
46
30
172
32
22
44
40
38
34
70
54
18
64

FIG. 29

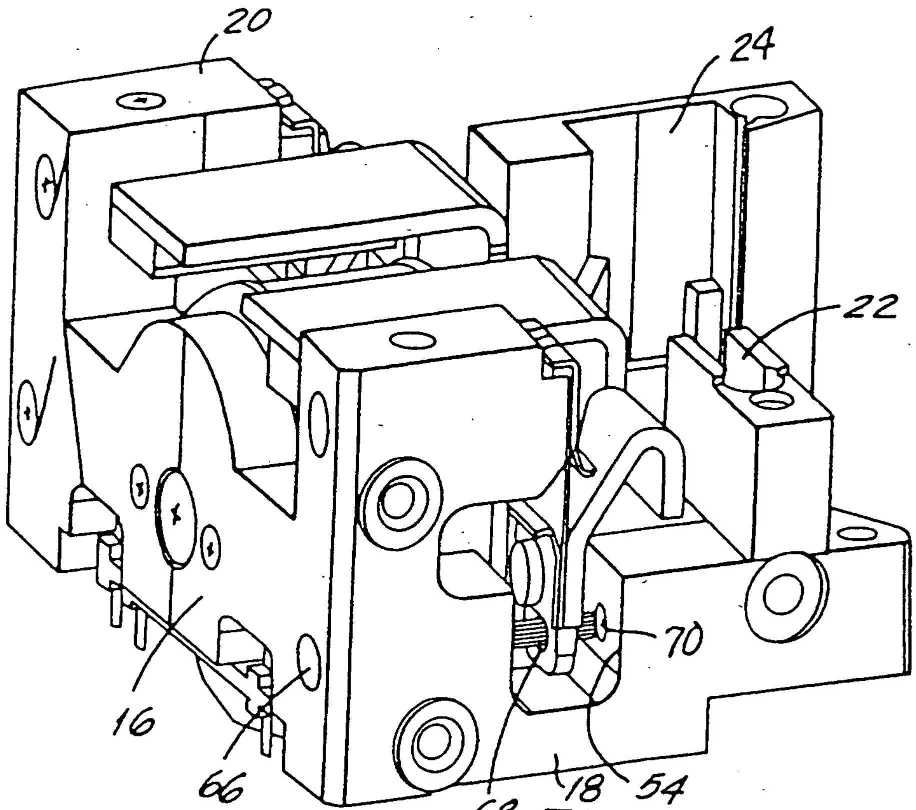

20
24
22
70
16
66
68
18
54

FIG. 30

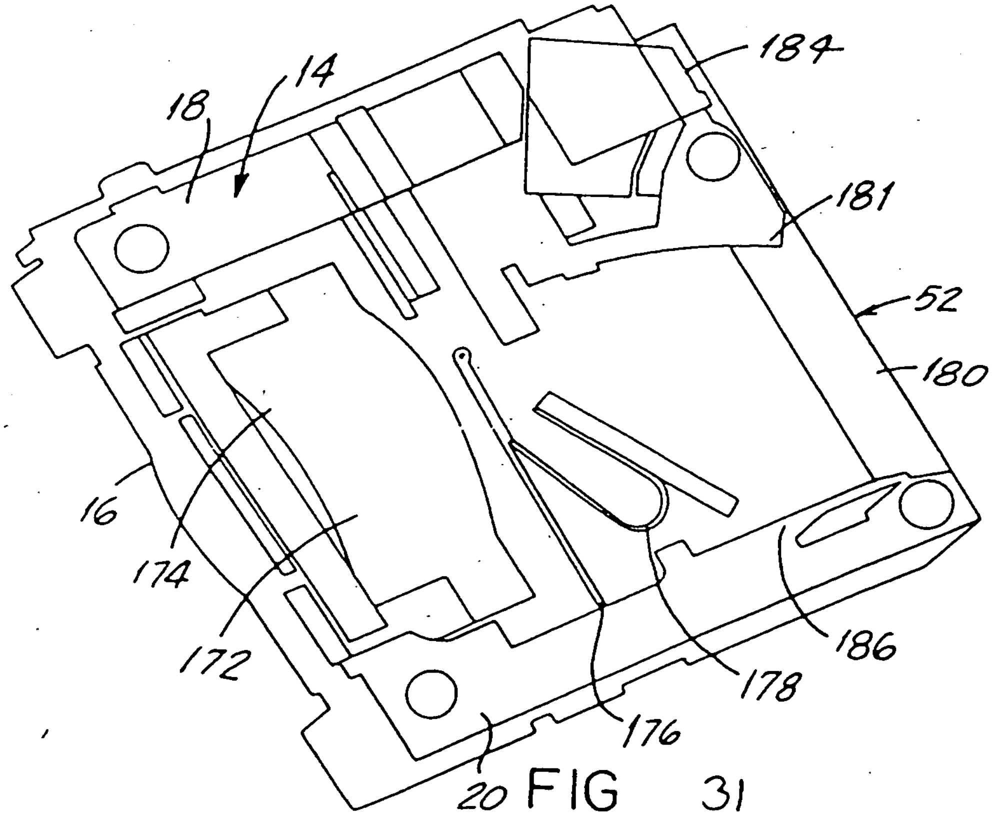

18
14
184
181
52
180
16
174
172
176
178
186
20

FIG 31